TESTING THE INTENSIFICATION HYPOTHESIS FOR EU AGRICULTURE*

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This paper tests the so called "intensification hypothesis" for EU agriculture on an intertemporal and interspatial base, using a panel data set for the 1961-1994 period. The empirical results indicate the acceptance of this hypothesis for all countries, except Portugal. Thus, output increases in EU agriculture – resulting from increased price support - will result in a higher fertiliser/hectare ratio, i.e., in greater intensification of production and possibly in more negative environmental impacts. The strength of this relationship however, differs among EU countries. The relationship between the intensification of agricultural production and irrigation technology, on the one hand and production structure (as is reflected in the crop/livestock ratio), on the other, is also explored. The empirical results may provide some insights for designing different environmental policies for different countries or group of countries (e.g. northern and southern EU countries).

Key words: intensification hypothesis, agricultural intensification, intertemporal and interspatial analysis, agriculture and environment, EU environmental policy.

1. Introduction.

It has been extensively argued in the literature (e.g. deWit, 1988; Bonnieux and Rainelli, 1988; Abler and Shortle, 1992) that higher levels of protection provide incentives for farmers to produce more, and in doing so they increase the use of polluting inputs, mainly fertilisers and pesticides - to the extent that these are considered to be normal inputs [1] Developments in EU agriculture have confirmed the above argument, as it is generally recognised, that high farm prices, achieved through the Common Agricultural Policy (CAP), have been a major cause of the impressive output growth which has been taking place during the past 3 or 4 decades. This development has been associated with the increase in the intensity of agricultural practices (e.g. production methods), i.e., the increase in input use (mainly fertilisers and pesticides) per unit of agricultural land (hectare), as well as the increase in stocking density (e.g. livestock unit/hectare)[2]. This process of *production intensification* in agriculture - often referred to in the literature as *agricultural intensification* (see Lewandrowski et al., 1977) - has in many cases also led to the use of marginal (less productive) land, which was brought into cultivation through irrigation and the extensive use of various intermediate inputs - especially fertilisers and pesticides[3]. The process of agricultural land expansion has been described by a number of authors as *agricultural extensification* (Ibid. p. 405).

The negative environmental implications of the *intensification* process in agricultural production have been recognised by policy makers and academic researchers alike and have been the subject of extensive research and debate. According to Lewandrowski et al. (1997: 407), these include: (a) soil erosion and sedimentation of surface water; (b) degradation of air quality; (c) soil productivity losses; (d) losses in biological diversity; (e) damages to ecosystem functioning; (f) nuisances; (g) contribution to global climate change through the greenhouse effect; (h) acid deposition; and (i) destruction of landscape amenities. The use of marginal and highly erodible land for agricultural purposes in particular, causes sediment and chemical runoff into surface water, while it affects negatively wildlife habitat and diversity of plants and animals through conversion of forests, wetlands, and other natural features to agricultural uses (Ibid, p. 407-408). All these implications may be considered as negative externalities and provide the framework for analysing the environmental effects of agricultural production.

While the above environmental implications of intensive agricultural production characterise mainly northern EU countries, Mediterranean regions face different environmental impacts from agricultural activity. On, the one hand, the gradual abandonment of traditional/extensive production systems in a number of areas of the uplands (as a result of the low economic competitiveness of such systems under a changing socio-economic context) has affected negatively the environment and the landscape through an increase in the 'desertification' process[4] and the conditions leading to soil erosion; on the other hand, the consequent movement of the population and agricultural activity to the more fertile areas of the low-land, resulted in limited intensification of these areas. At the same time, traditional/extensive farm practices are still present to a significant extent mostly on the uplands of these countries. Such practices, also known as 'low-intensity' farming practices, are associated with high nature conservation interest and sustainable agriculture. For all these reasons, the overall intensification of farm production in southern EU countries is limited relatively to northern countries and the environmental damage from this process less severe. However, even though limited, the process of intensification shows rising trends (Caraveli, 1998, a, b, c).

The main objective of this paper is to test the so called «intensification hypothesis» - which asserts that farm price support leads to greater input use per unit of land in production (see Lewandrowski et al., 1997) - for EU agriculture. Following Lewandrowski et al., input use per unit of agricultural land is measured by fertiliser use per hectare. The analysis is based on data for the 1961-1994 period: A panel data set is constructed for 14 European countries (Austria, Belgium-Luxembourg, Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, and U.K.)[5] and the intensification hypothesis is tested on an intertemporal and interspatial base. This also implies testing for the existence of statistically significant differences in fertiliser use per hectare among EU countries. In this way, a second hypothesis is also tested, namely, that the degree of intensification is lower in southern (Mediterranean) relatively to northern EU countries. Empirical findings reveal that southern countries show a lower fertiliser/hectare ratio but faster annual growth rates over the period under consideration. The empirical results may provide some insights for designing different environmental policies for northern and southern EU countries, at least for crop production with spatially differentiated standards or quotas in use.

2. Conceptual Framework.

Most recent studies on environmental impacts of agricultural policies (e.g. de Wit, 1988; Bonnieux and Rainelli, 1988; Abler and Shortle, 1992; Just and Antle, 1990; Hrubovcak et al., 1990; La France, 1992; Smith, 1992; Harold and Runge, 1993; Lewandrowski et al., 1997) emphasise the difficulty in linking, both theoretically and empirically, agricultural policies, farm practices and environmental problems in rural areas. According to Just and Antle, the major problem is that environmental impacts associated with various field level operations do not aggregate to the larger geographical units that are relevant to policy issues (see also Lewandrowski et al., 1997:405). Thus, while the relationship between agricultural production and environmental damages is site specific, determined mainly by farm practices in the area, agricultural policies are issued for larger geographical regions. In the case of the EU, such a large geographical unit comprises the 15 member-countries. This creates serious problems in relating micro farm data to aggregate national data. Nevertheless, Just and Antle, have shown that the intensification of agricultural production can be directly linked to environmental damages when (i.e. iff) the quantity of land used for production as well as land environmental characteristics are held constant.

Based on this finding, in the analysis that follows it is assumed that at a national level land environmental characteristics are more or less homogeneous. Moreover, by using the fertiliser/hectare ratio as an intensification indicator it is assumed that land is implicitly held constant. These assumptions satisfy Just and Antle's prerequisites for linking the fertiliser/hectare ratio to environmental damages. Then, to the extent that agricultural policies generally - mainly through higher producer prices -stimulate crop and livestock production, the intensification hypothesis may be stated in terms of the interrelationship between the fertiliser/hectare ratio and output increase. This also allows us to overcome an important shortcoming: the fact that time series for farm product prices are not available on a long-term basis and cannot be obtained from a single source. Moreover, by stating the intensification hypothesis in terms of agricultural output instead of prices, it is implicitly assumed that farmers aim at cost minimisation rather than profit maximisation[6] and, thus, the fertiliser/hectare ratio is expressed in a form of compensated derived demand. The reason for not using the prices of other inputs - as would be expected - was previously explained in relation to product prices and is simply lack of data. For analytical purposes, a simple double-logarithmic functional form is used with the corresponding estimated coefficients representing elasticities.

Support within the framework of the CAP consists of a nexus of price support measures, production controls (e.g. quotas) and land set-aside schemes, all of which affect the level of production directly or indirectly. Intuitively, the impact of agricultural policies on the intensification of farm production can be decomposed into output and substitution effects. For example, price support measures stimulate production through higher producer prices. As long as fertiliser is considered a normal input, output increases will result in an increased use of fertiliser per unit of land. This corresponds to the output effect. Also, it has extensively been argued that subsidies are capitalised into land values, raising the relative price of agricultural land. This induces substitution of non-land factors of production for land along a given isoquant. Therefore, fertiliser/hectare should be expected to increase. This constitutes the substitution effect. On the other hand, land set-aside schemes, by restricting the quantity of land in production, raise its price and encourage the use of non-land inputs (substitution effect), but it is not certain if they lead to lower production levels (Roberts et al., 1996). Finally, production quotas, by restricting output (output effect) result in a decrease of fertiliser/hectare ratio.

From the above mentioned intuitive observations, a positive relationship should be expected between *agricultural intensification* and farm output per hectare. In the analysis that follows only crop output is examined. Data are obtained from FAO Statistical Yearbook, where a crop production index is available in a moving average base (1979-1981=100). Data on fertiliser and cultivated land are obtained from the same source. This time series data covering the period 1961-1994 for each country are pooled together to increase the efficiency of the estimated parameters. The model is estimated in a recursive form including intercept dummies to take into account interspatial differences in the fertiliser/hectare ratio.

To explore further the evolution of production intensification in EU agriculture, two more ad hoc relationships are hypothesised, relating the fertiliser/hectare ratio to the percentage of land irrigated and the crop/livestock ratio, respectively. The former may be viewed as an index of technical change, capturing changes induced by biological/chemical innovations (i.e., high yield varieties). Hayami and Ruttan (1985) showed that high yield varieties, developed by plant breeding, require more extensive application of fertilisers to achieve the expected high yields, as well as the availability of irrigation technology. This implies that, gradually, the proportion of irrigated land increases. Thus, a positive relationship is expected between irrigated land and intensification of production. This relationship is particularly important for EU agriculture, since - as was previously noted - it has been estimated that most of its output growth was achieved through yield improvements[7].

A third relationship, linking the intensification indicator to the crop/livestock ratio, is also examined, so that potential differences in the fertiliser/hectare ratio between northern and southern EU countries can be deterred. It is well known that northern EU countries have a higher share of livestock production in total farm production and, thus, a relatively lower crop/livestock ratio. It would be reasonable to expect that a higher share of crop production in total farm production is associated with higher yields and increased fertiliser use per unit of land; it is therefore hypothesised that a positive relationship exists between the fertiliser/hectare ratio and the crop/livestock production ratio. An assumption needs to be made here, that there are no physical differences between countries, since if, for example, more livestock is produced in confined quarters, i.e. hog barns, then the above relationship becomes meaningless.

3. Hypotheses, Modelling and Empirical Results.

We first examine the hypothesis that there are intertemporal and interspatial differences in the fertiliser/hectare ratio among EU countries. A linear regression is specified with the logarithm of this ratio used as the dependent variable. A constant and a time trend are included as explanatory variables in a recursive form, with the corresponding dummies, to take into account interspatial differences. Algebraically, this relationship has the following form:

$$\ln(F/A) = \sum_{(i=1,2,..14)} a_i D_i + \sum_{(i=1,2,..14)} b_i D_i t + cD_0 \qquad (1)$$

where F/A is the ratio of fertilisers to area (hectares of cultivated land); D_i are the country-specific intercept dummies; t is the time trend; c, a_i, b_i are the estimated coefficients; D_0 is the regional dummy (north-south).

This specification allows the direct derivation of annual average growth rates per country from the estimated coefficient of the time trend variable. The set of estimated coefficients is presented in Table 1.

Table 1

The empirical findings show that only in four countries, namely Austria, Belgium-Luxembourg, Germany and Sweden, intertemporal differences in the fertiliser/hectare ratio are statistically insignificant. In all other countries, there are significant changes in fertiliser use over the 1961-1994 period, i.e., the fertiliser/hectare ratio increased over time. The estimated average annual rates of increase are reported on Table 3. It can be seen that these growth rates are close to zero for the four countries mentioned above (a negative growth rate is found for Germany). Furthermore, they are greater than 1% annually for all southern EU countries, as well as for Finland and the U.K. At the same time it is evidenced that these countries also have the smaller fertiliser/hectare figures. Thus, it may be argued that agricultural development in the EU, during the 1961-1994 period, is characterised by the effort of countries with low-intensity farm production to achieve higher production levels by intensifying their practices.

The second interesting feature, apparent in Table 1, is the statistical significance of the regional dummy, specified to take values 0 and 1, for northern and southern EU countries, respectively. This means that there are significant differences in the intensification of farm production (which is measured by the fertiliser/hectare ratio) between the two groups of countries. The positive sign indicates that fertiliser use per hectare is, on average, greater in northern than in southern countries, despite the fact that the average annual growth rates achieved in the 1961-1994 period were faster in southern countries.

Table 2

Table 3

Despite these wide regional differences, it can be statistically accepted that intra-group differences in both the level and the rate of growth of the fertiliser/hectare ratio are significant (see Table 2). The statistical hypotheses that the fertiliser/hectare ratio, as well as its growth rate, are similar within either the northern or the southern group of countries are therefore rejected. This means that the two groups of countries are not homogeneous in terms of *agricultural intensification* (as would probably be expected). In an attempt to check if this hypothesis testing is affected by the inclusion of Scandinavian countries into the northern group, the corresponding test suggests that these countries have achieved similar growth rates, but still have different degrees of production intensification in their farm sectors than the rest of the northern countries.

The empirical results, on the basis of which the intensification hypothesis is tested, are presented in Table 4.

Table 4

These results correspond to a double-logarithmic relation between the fertiliser/hectare ratio and output, specified in a recursive form, along with dummy (country specific) intercept terms:

$$\ln(F/A) = \sum_{(i=1,2,..14)} a_i D_i + \sum_{(i=1,2,..14)} b_i D_i \ln Y + cD_0 \qquad (2)$$

where Y represents farm output (measured by gross value of agricultural production in constant prices).

The double-logarithmic specification allows the estimated coefficients corresponding to output to be interpreted as elasticities. It is important to note that the region specific intercept dummy becomes statistically insignificant when output enters as an explanatory variable in the fertiliser/hectare equation.

The empirical results lead to the acceptance of the intensification hypothesis for all countries, except Portugal, as the estimated coefficients b_i are positive. Nevertheless, on statistical grounds, the intensification hypothesis holds only marginally for Austria, Belgium-Luxembourg, Denmark and Germany since the estimated coefficients are positive but statistically insignificant. Thus, according to our results, output increases - which are assumed to be the outcome of price support (e.g. increased prices) in EU agriculture - lead to a higher fertiliser/hectare ratio, i.e. in greater production intensification and environmental damages. The strength of this relation differs, however, among EU countries.

From the estimated coefficients reported in Table 4, it is evidenced that the fertiliser/hectare ratio has an elastic response to output changes in southern EU countries, except Portugal, as well as in Finland and the U.K.; this ratio is found to be inelastic for the rest of EU countries. This implies that equal proportional changes in output will result in greater proportional changes in the fertiliser/hectare ratio of the southern group of countries and, consequently, in more severe environmental damages. Nevertheless, it cannot be argued with certainty, that higher price support will induce more negative environmental impacts in southern EU countries, as this effect also depends on supply elasticity. This would be the case only if agricultural supply responses were uniform across EU countries.

To explore further intra-regional group differences in the intensification of farm production, more statistical hypotheses - concerning similar fertiliser/hectare response -to output changes are tested. The results, reported on Table 5, indicate that this may only be true for Scandinavian countries. In either the northern or the southern group of countries, the magnitude of the corresponding elasticity differs statistically among countries. These differences seem to be larger in the southern group.

Table 5

The results concerning fertiliser/hectare responses to changes in the percentage of land irrigated are reported in Table 6.

Table 6

By utilising the double-logarithmic specification:

$$\ln(F/A) = \sum_{(i=1,2,..14)} a_i D_i + \sum_{(i=1,2,..14)} b_i D_i \ln I + cD_0 \qquad (3)$$

where I is the proportion of land irrigated, the estimates of b_i may be interpreted as elasticities. Country and region specific intercept dummies are also included in the regression equation. The coefficient of the regional dummy is found to be statistically different than zero, while the country-specific intercept terms are zero for Austria, Belgium-Luxembourg, France, Germany, Italy, Spain and the U.K.

The empirical results indicate that the fertiliser/hectare ratio is invariable to increases in the proportion of hectares irrigated in Austria, Germany, Portugal and Sweden. Quite interestingly, a 1% increase in irrigated land results in a greater than 1% increase in the fertiliser/hectare ratio in all southern countries, except Portugal and

France; the corresponding elasticity figure is consistently less than one in the case of northern countries. This implies that any policy measures, aiming (by creating the proper incentives) at the increase of the adoption and diffusion rates of irrigation technologies, may result in relatively more severe environmental damages in southern countries; this is so, since the impact of policy (price supports) on fertiliser use per hectare was found to be relatively more significant in the southern group of countries. However, the statistical results appearing in Table 7, reveal that only among Scandinavian countries similar elasticity magnitudes can be identified. The response of the fertiliser/hectare ratio to changes in irrigated land differs significantly among all other countries, regardless of the group in which they belong.

Table 7

Finally, in order to determine a potential relationship between *agricultural intensification* and structure of production, as is reflected in the crop/livestock ratio, a linear regression was set up, with country-specific intercept dummies and the log of the crop/livestock ratio used as explanatory variables:

$$\ln(F/A) = \sum_{(i=1,2,..14)} a_i D_i + \sum_{(i=1,2,..14)} b_i D_i \ln(Y_c/Y_L) + cD_0 \qquad (4)$$

where Y_c and Y_L represent crop and livestock production, respectively.

The results are presented in Table 8.

Table 8

A positive relationship between the fertiliser/hectare and the crop/livestock ratio was found only for Denmark, Finland, France, Greece, Spain and the U.K. The fertiliser/hectare ratio was found to be invariable to changes in the crop/livestock ratio for the case of Austria, Belgium-Luxembourg, Germany, the Netherlands, Norway and Sweden. A statistically significant negative relationship was found for Italy and

Portugal. In three southern countries, namely France, Greece and Spain, fertiliser use per hectare seems to be very sensitive to changes in the crop/livestock ratio. In particular, a 1% shift of agricultural production towards crops results in a 1.73, 1.96 and 1.34% increase in the fertiliser/hectare ratio, respectively. It should be noted that these three countries show the most "unfavourable" (i.e., more biased toward crops) crop/livestock ratios among EU countries. On the other hand, the fertiliser/hectare ratio response to the crop/livestock ratio was found to be inelastic in all northern and Scandinavian countries.

Concerning the same relationship, important similarities were found in the magnitude of elasticity within the northern and Scandinavian countries' groups, while this was not the case for southern countries (see Table 9). This is so, since three out of five southern countries exhibited positive and elastic responses, whereas two of them, namely Italy and Portugal, showed negative ones.

Table 9

4. Concluding Remarks

The empirical results suggest the acceptance of the intensification hypothesis for all EU countries, except Portugal. Thus, output increases in EU agriculture – which are asssumed to be the outcome of high guaranteed prices - will result in a higher fertiliser/hectare ratio, i.e., in greater intensification of farm production and most probably in even more negative environmental impacts . These responses are however more elastic for the southern EU countries, indicating that higher price support could induce severe environmental damages in these countries.

It has also been found that in all southern countries, except Portugal and France, irrigation technologies affect significantly the level of production intensification. Thus, any kind of policy or incentives aimed at increasing the adoption and diffusion of irrigation technologies may result in relatively more severe environmental damages in southern countries, due to its larger impact on fertiliser use per hectare in these countries.

A third interesting finding suggests that production structure - expressed by the crop/livestock ratio - is a significant determinant of the intensification of production only for those countries which face the most “unfavourable” crop/livestock ratios (i.e. more biased towards crops) among EU countries, namely France, Greece and Spain.

The empirical results may provide some insight for designing different environmental policies for different countries or groups of countries (e.g. northern and southern countries). Within this context, policy measures (price or structural) aiming at the re-organisation of agricultural production (e.g. at reducing the crop/livestock ratio) in specific countries may have significant effects in reducing environmental damages.

Notes

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[1] Some authors, however, attribute greater significance to the role of technological change in the achievement of higher production levels and the creation of surpluses than to that of farm support policies (see for example Buckwell, 1990). Still, it can be argued that high farm support leads to the adoption of improved technologies in farm production – see footnote no. 2.

[2] According to Murphy, Furtan and Schmitz (1993), most of output growth in EU agriculture has been achieved through yield improvements induced by the incentives given under CAP support, which led to the adoption of yield-increasing technology.

[3] It should of course be mentioned that more intensive use of good agricultural land may make the use of marginal and highly erodible land for agricultural purposes unnecessary.

[4] The term refers to the reduction of the soil's ability to be productive, as a result of either human acitvities (i.e. over-stocking after abandonment of cultivation) or long-term climatic changes (Ratification of the Rio Conference, 6 March 1997, 1(32) - in Greek).

[5] Ireland is not included in the data set due to data unavailability for some of the dependent variables incorporated in the model.

[6] In their recent study (1997), Lewandrowski et al. tested the intensification hypothesis by using PSEs as proxies for agricultural support, but they restricted their analysis to the 1982-1987 period due to lack of the necessary price data.

[7] Of course it should be noted that EU yields have increased on non- irrigated land too.

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Table 1: Estimated F/A for EU Countries, 1961-1994.

Variable	Estimated Coefficient	t-statistic
a_1	-2.029	-10.93
a_2	-1.196	-6.45
a_3	-2.110	-11.37
a_4	-2.464	-13.28
a_5	-2.706	-7.58
a_6	-1.476	7.95
a_7	-3.764	-10.55
a_8	-3.676	-10.01
a_9	-0.906	-4.88
a_{10}	-1.996	-10.75
a_{11}	-3.888	-10.90
a_{12}	-4.130	11.57
a_{13}	-2.447	-13.18
a_{14}	-2.058	-11.09
b_1	0.0028	0.91
b_2	0.0030	1.01
b_3	0.0096	3.16
b_4	0.0134	4.44
b_5	0.0237	7.83
b_6	-0.0012	-0.39
b_7	0.0411	13.59
b_8	0.0400	12.63
b_9	0.0059	1.94
b_{10}	0.0097	3.20
b_{11}	0.0194	6.40
b_{12}	0.0315	10.40
b_{13}	0.0027	0.88
b_{14}	0.0206	6.83
C	0.442	2.51
R^2=0.94		
F(28,433)=281.32		

Notes:

(1) "A" refers to area, which is measured by hectares.

(2) (1) refers to Austria, (2) to Belgium-Luxembourg, (3) to Denmark, (4) to Finland, (5) to France, (6) to Germany, (7) to Greece, (8) to Italy, (9) to Netherlands, (10) to Norway, (11) to Portugal, (12) to Spain, (13) to Sweden, and (14) to U.K.

Table 2: Hypotheses Testing for Similar F/A Use Patterns among EU Countries, 1961-1994.

Hypothesis	Degrees of Freedom	Calculated x^2-statistic	Tabulated x^2-statistic at 5%
Similar F/A in northern EU countries	8	87.73	15.51
Similar F/A in southern EU countries	4	85.69	9.49
Similar F/A in Scandinavian countries	2	20.27	5.99
Similar F/A in northern EU countries	5	75.30	11.07
Similar F/A growth in northern EU countries	8	24.93	15.51
Similar F/A growth in southern EU countries	4	9.98	9.49
Similar F/A growth in Scandinavian countries	2	3.26	5.99
Similar F/A growth in northern EU countries	5	26.44	11.07

Table 3: Estimated F/A Use and its Average Annual Growth Rate for EU Countries, 1961-1994.

Country	Fertiliser per Hectare	Annual Growth Rate (%)
Austria	0.205	0.28
Belgium-Luxembourg	0.470	0.30
Denmark	0.189	0.96
Finland	0.133	1.34
France	0.162	2.37
Germany	0.356	-0.11
Greece	0.056	4.11
Italy	0.063	4.00
Netherlands	0.629	0.59
Norway	0.212	0.97
Portugal	0.050	1.94
Spain	0.039	3.15
Sweden	0.135	0.27
U.K.	0.199	2.06

Table 4: Estimated F/A Response to Output Growth for EU Countries, 1961-1994

Variable	Estimated Coefficient	t-statistic
a_1	-1.722	-9.87
a_2	-0.897	-5.15
a_3	-1.702	-9.78
a_4	-1.960	-11.26
a_5	-1.670	-4.85
a_6	-1.240	-7.12
a_7	-2.324	-6.74
a_8	-2.213	-6.59
a_9	-0.523	-2.99
a_{10}	-1.547	-8.87
a_{11}	-3.010	-8.71
a_{12}	-2.960	-8.59
a_{13}	-2.099	-11.97
a_{14}	-1.346	-7.70
b_1	0.232	1.14
b_2	0.018	0.09
b_3	0.290	1.57
b_4	1.392	5.69
b_5	1.879	8.30
b_6	0.158	0.88
b_7	1.832	13.61
b_8	3.072	12.87
b_9	0.307	2.55
b_{10}	0.643	2.94
b_{11}	-0.515	-2.05
b_{12}	1.272	10.47
b_{13}	0.632	2.57
b_{14}	1.178	7.02
C	0.195	1.14
R^2=0.94		
F(28,433)=279.59		

Note: (1) refers to Austria, (2) to Belgium-Luxembourg, (3) to Denmark, (4) to Finland, (5) to France, (6) to Germany, (7) to Greece, (8) to Italy, (9) to Netherlands, (10) to Norway, (11) to Portugal, (12) to Spain, (13) to Sweden, and (14) to U.K.

Table 5: Hypotheses Testing for Similar F/A Responses to Output Growth among EU Countries, 1961-1994.

Hypothesis	Degrees of Freedom	Calculated x^2-statistic	Tabulated x^2-statistic
Similar elasticity in northern EU countries	8	25.64	15.51
Similar elasticity in southern EU countries	4	29.54	9.49
Similar elasticity in Scandinavian countries	2	3.28	5.99
Similar elasticity in northern EU countries	5	25.69	11.07

Table 6: Estimated F/A Responses to Irrigated Land for EU Countries, 1961-1994.

Variable	Estimated Coefficient	t-statistic
a_1	0.923	0.28
a_2	1.549	1.14
a_3	-1.558	-8.37
a_4	-1.398	-6.94
a_5	-0.522	-1.36
a_6	-0.294	-0.36
a_7	-0.958	-2.67
a_8	2.096	0.96
a_9	-0.449	-2.45
a_{10}	-1.182	-5.48
a_{11}	-4.328	-7.38
a_{12}	-0.042	-0.09
a_{13}	-2.111	-9.04
a_{14}	1.238	0.59
b_1	0.477	0.88
b_2	0.390	1.96
b_3	0.133	4.20
b_4	0.175	7.06
b_5	0.522	8.69
b_6	0.347	1.47
b_7	1.356	14.59
b_8	2.989	13.19
b_9	0.453	4.15
b_{10}	0.217	4.45
b_{11}	-0.248	-0.80
b_{12}	1.740	11.47
b_{13}	0.062	1.53
b_{14}	0.708	6.48
c	0.403	2.45
R^2=0.95		
F(28,433)=321.99		

Note: (1) refers to Austria, (2) to Belgium-Luxembourg, (3) to Denmark, (4) to Finland, (5) to France, (6) to Germany, (7) to Greece, (8) to Italy, (9) to Netherlands, (10) to Norway, (11) to Portugal, (12) to Spain, (13) to Sweden, and (14) to U.K.

Table 7: Hypotheses Testing for Similar F/A Responses to Irrigated Land among EU Countries, 1961-1994.

Hypothesis	Degrees of Freedom	Calculated x^2-statistic	Tabulated x^2-statistic
Similar elasticity in northern EU countries	8	25.32	15.51
Similar elasticity in southern EU countries	4	36.96	9.49
Similar elasticity in Scandinavian countries	2	3.78	5.99
Similar elasticity in northern EU countries	5	26.62	11.07

Table 8: Estimated F/A Responses to Crop/Livestock Ratio for EU Countries, 1961-1994.

Variable	Estimated Coefficient	t-statistic
a_1	-1.010	-2.21
a_2	-0.230	-0.60
a_3	-1.020	-3.53
a_4	-1.043	-3.66
a_5	0.108	0.20
a_6	-1.621	-3.56
a_7	0.003	0.01
a_8	-3.399	-5.28
a_9	-0.577	-1.25
a_{10}	-0.655	-0.92
a_{11}	-3.075	-6.18
a_{12}	-1.859	-3.93
a_{13}	-1.587	-5.85
a_{14}	0.243	0.59
b_1	0.406	1.04
b_2	0.321	1.13
b_3	0.378	2.10
b_4	0.470	3.76
b_5	1.728	4.49
b_6	-0.639	-1.75
b_7	1.964	7.44
b_8	-1.648	-3.66
b_9	-0.289	-0.83
b_{10}	0.307	0.91
b_{11}	-0.637	-3.19
b_{12}	1.340	4.79
b_{13}	0.355	1.76
b_{14}	0.924	4.08
c	-0.120	-2.53
R^2=0.90		
F(28,433)=149.40		

Note: (1) refers to Austria, (2) to Belgium-Luxembourg, (3) to Denmark, (4) to Finland, (5) to France, (6) to Germany, (7) to Greece, (8) to Italy, (9) to Netherlands, (10) to Norway, (11) to Portugal, (12) to Spain, (13) to Sweden, and (14) to U.K.

Table 9: Hypotheses Testing for Similar F/A Responses to Crop/Livestock Ratio among EU Countries, 1961-1994.

Hypothesis	Degrees of Freedom	Calculated x^2-statistic	Tabulated x^2-statistic
Similar elasticity in northern EU countries	8	2.24	15.51
Similar elasticity in southern EU countries	4	26.30	9.49
Similar elasticity in Scandinavian countries	2	0.18	5.99
Similar elasticity in northern EU countries	5	3.45	11.07