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THE QUALITY OF NATURAL RESOURCES AND THE MEASUREMENT OF EFFICIENCY FOR THE AGRICULTURAL PRODUCTION IN THE ITALIAN PROVINCES

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Summary
Some indicators of natural resource quality, relevant for agricultural production, have recently been reintroduced in the literature on multilateral agricultural productivity comparisons.
Objective of this paper is to perform a sensitivity analysis of the impact on the specification of a stochastic frontier production function and on the measurement of technical efficiency of these indicators. In the present study, they are introduced as non-conventional inputs in a stochastic frontier production function estimated for Italian agriculture over the period 1980-90 with provincial data. The conventional inputs and the indicators of natural resources are those usually employed in multilateral comparisons; particularly, the proxies of natural resources quality are: land fertility, measured as a weighted average of cereal yields, and rainfall from October to March.

Key-words: aggregate production function, natural resource quality indicators, stochastic frontier, sensitivity analysis, mispecification impact on efficiency estimates.

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Riassunto
Indicatori di qualità delle risorse naturali, rilevanti nella produzione agricola, sono stati recentemente reintrodotti nella letteratura sui confronti multilaterali di produttività nel settore primario.
Scopo di questo lavoro é eseguire un'analisi di sensitività relativa all'impatto di questi indicatori sulle misure di efficienza tecnica. Nel presente lavoro, tali indicatori sono introdotti come fattori produttivi non convenzionali nella specificazione di una funzione di produzione di frontiera stocastica, stimata per l'agricoltura italiana degli anni '80 con dati provinciali. Le variabili relative ai fattori produttivi convenzionali e agli indicatori di qualità delle risorse naturali sono quelle abitualmente utilizzati nei confronti multilaterali; in particolare, gli indicatori di qualità delle risorse naturali sono: fertilità della terra, misurata come media ponderata delle rese cerealicole, e precipitazioni, cadute da ottobre a marzo.

***Parole chiave**: funzione di produzione aggregata, indicatori di qualità delle risorse naturali, frontiera stocastica, analisi di sensitività, impatto della mispecificazione sulle stime di efficienza.*

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Introduction*

Several authors have raised the issue of including the stock of national natural resources in the measurement of productivity for the whole economy (Diewert, 1980) and particularly for the agricultural sector (Lau, Yotopoulos, 1989,1991; Oskam,1991b). Some direct indicators of natural resources quality have been used in a few agricultural productivity estimates. The theoretical rationale is to take into account 'non-conventional' inputs beyond farmer control but affecting production level.

Generally, it is not easy to measure the quality of natural resources, to find data on them and to use appropriate proxies. Up to now, in comparisons of territorial aggregates, which are heterogenous in terms of natural resources relevant for agricultural production, the indicators proposed are essentially correlated to precipitation and land quality but there is not any evidence on how they perform.

Objective of this paper is a sensitivity analysis of the impact of the two indicators above mentioned on the estimates of the productive efficiency in the agriculture of the Italian provinces during the '80s. The approach followed is a stochastic frontier production function, estimated with a panel data. Land quality is measured as a weighed average of cereal yields and precipitation is measured from october to march.

In particular, this study intends to verify whether and how much the ranking of efficiency measures changes without these proxies and which proxy more affects the results.

Chapter 1 reviews the studies on multilateral agricultural productivity comparisons performed with the mentioned indicators of natural conditions. In chapter 2 they are briefly described the measurement of conventional inputs, the proxies of natural resources and the production function specification used in this study. Finally chapters 3 and 4 report the results in terms of regression estimates and efficiency levels obtained in the analysis performed with and without the indicators of natural resource quality. Concluding remarks on the results of this analysis are reported in chapter 5.

1. MULTILATERAL PRODUCTIVITY COMPARISONS AND NATURAL RESOURCES INDICATORS

1.1 The concept of perceived productivity

In recent multilateral productivity literature, it has been paid attention on the measurement of the capital stock of natural resources and its depreciation (Diewert, 1980).

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Data are lacking for an appropriate evaluation of this stock and even more so for its depreciation. Therefore, conventional productivity measurement may account for only part of the inputs used in agricultural production. This can cause an overevaluation of measured technical efficiency and productivity growth, simply due to a higher quality of some natural resources, which are excluded from the measurement.

Because of this, Alston et al. (1995) stress that most of the total factor productivity (TFP) indexes measured up to now in the literature are misnamed and misinterpreted. They introduce the concept of perceived productivity that refers to the illusion of technological change due to the omission of relevant inputs or outputs from the computation; since the quality of natural resources influencing agricultural production can change over time, they also dynamize the Hayami, Ruttan's concept of meta-production function[1].

An estimate of the difference between perceived and real productivity levels is in Oskam (1991). In the TFP measurement of the Dutch agriculture over the period 1949-1988, he introduced a weather index. Compared with the annual rate of perceived productivity, the average measure with the weather index is 6% higher. As Oskam observed, the long term productivity figures seem not to be very sensitive to weather influences but short term calculations may improve considerably and the corrections for weather influences become important for the analysis of productivity between different subperiods within the entire period that he examined.

1.2. Indicators of natural resources quality used in the multilateral econometric approach

The dependence of agricultural production on meteorological events is generally suppressed in the econometric analysis of agricultural productivity on the assumption that in agriculture weather phenomena are reflected in the error term. For time-series data changes in environment could be considered transitory and reflected in the disturbance but this assumption is not valid for cross-country studies where different environments prevail (Mundlak, Hellinghausen 1982).

Besides, assuming that weather phenomenon is entirely reflected in the error makes it less tenable the usual assumption of indipendence among input variables and error term. The correlation between the weather-affected error and predetermined inputs variables can be very small but this is not likely for harvest-associated inputs, such as labor (Griliches, 1963).

The omission of relevant inputs from productivity measurement is an old problem in the efficiency literature: as Stigler (1976) has observed, measured inefficiency may be a reflection of a failure to incorporate the right variable and the right constraint and to specify the right economic objective of the production

[1]Alston et al. intend the intertemporal meta-production function as a dynamic relationship that defines current and future production possibilities. Corresponding to this function, a multi-period measure of total factor productivity could be defined by aggregating all outputs and all inputs over all time.

unit. For the econometric approach to efficiency analysis, it can be considered as a case of functional mispecification due to variable omission.

A few authors have introduced some indicators of natural resources quality in multilateral agricultural productivity comparisons. These studies, summarized in table 1, are: Bhattacharje (1955), Griliches (1963), Mundlak, Hellinghausen (1982), Lau, Yotopolous (1989), Frisvold, Ingram, (1995).

Bhattacharje (1955) converted pasture land into arable land equivalents. He calculated the quality weights in relation to the number of cattle that a unit area of each of the two classes can support.

Griliches (1963) used the land rent as a proxy of cross-sectional differences in the quality of agricultural land.

Mundlak, Hellinghausen (1982) used the potential dry matter, that is a potential land yield, achievable in case of optimal precipation and soil condition, and the factor of water deficit, that is the ratio of actual transpiration to potential transpiration, intended as a measurement of water availability. These data were extracted from Buringh et al. (1975), who mapped the world according to variables defining the potential for food production.

Lau, Yotopolous (1989) did not use direct indicator of natural resources quality but estimated country fixed effects[2], summarizing the basic physical and economic environment. The introduction of these effects in the production function estimation is proved to affect the estimates of the conventional input coefficients. However, even if it improves the regression fit, the use of country-specific effects is criticized (Mundlak, Hellinghausen, 1982) since these represent not only the physical environment but also the country's technology level.

Frisvold, Ingram, (1995) utilized a land quality index obtained from Peterson (1987) whose measure is a function of historic precipitation and the percentage of area devoted to pastures, irrigated crops and non-irrigated crops.

Table 1. Aggregate production functions with natural resource indicators

Regression parameters	Griliches	Bhattacharje	Mundlak Hellinhausen	Lau Yotopoulos	Frisvold Ingram
Functional form	CD	CD	CD varying coefficient	TL	CD
Production					
aggregate	*	*	*		
standardized				per farm	per hectare
Conventional inputs					
			first order coefficients		
Land	0,21	0,36	0,19	0,40	
Labor	0,23	0,30	0,53	0,40	0,60
Machinery	0,28	0,03	0,08	0,11	0,04
Fertilizer	0.21°	0,27	0,13	0,06	0,03

[2]The values of these country-specific parameters are given in Lau, Yotopolous (1991).

Livestock	0,18	0,04	0,23	0,14	0,19
Buildings	0,14				
			second order coefficients		
Machinery				0,01	
			for livestock production		
Livestock	0,41				
Intermediate inputs	-0,37				
Land	-0,23				
Natural resources indicators					
Land quality	price of land	weight for land	0,12		0,91
Water availability			0,00		
Irrigation			0,01		
Country fixed-effect				*	
Other non-conventional inputs					
Other variables				dummies	
Technical education	0.27°°			0,11	
Export growth					0,02
Calorie availability					0,35
Average labour productivity			0,23		
Returns to scale					
conventional inputs	1.16°°°	1,00	1,17	1,00	0,86
non-conventional inputs				1,11	1,21
Regression	cross-section	cross-section	pooled	pooled	panel
R-squared	0,99	0,94	0,98	0,87	0,95
N. spatial observations	68	22	58	43	28
Sample	US regions	DC's-LDC's	DC's-LDC's	DC's-LDC's	SSA
Period	1950	1950	1960-'65-'70	1960-'70-'80	1973-1985

° referred to non-livestock intermediate inputs

°° referred to general education

°°° computed by adding to the input X-coefficient, the coefficient of pX times with p=0.47, the average livestock percentage on total production in the sample

2. THE STOCHASTIC FRONTIER PRODUCTION FUNCTION

2.1. The stochastic frontier

Technical efficiency is estimated by using a single-output stochastic frontier production function (Fried et al., 1993):

(1) $y_i = f(x_i, \beta) + v_i - u_i$

where:

y_i = observed output of the *i*th unit;

x_i = vector of input levels for the *i*th unit;

β = parameter vector of frontier production function;
v_i =stochastic error for the *i*th unit;
u_i =productive inefficiency of *i*th unit;
i = 1, ..., N (number of units);

Potential output of the *i*th unit is:

(2) $y_i* = f(x_i, \beta) + v_i$

and technical inefficiency of the *i*th unit is equal to $y_i* - y_i$, that is:

(3) $[f(x_i, \beta) + v_i] - y_i$

.

By using panel data and referring to a linear production function, total residuals ($v_i - u_i$) can be decomposed:

(4) $y_{it} = \alpha_t + x_{it}\,\beta + v_{it} - u_{it}$

where:
u_{it} = technical inefficiency of the *i*th unit for time period t
t = 1,......,T (time periods)

Putting $\alpha_{it} = \alpha_t - u_{it}$ and replacing it into the (4):

(5) $y_{it} = \alpha_{it} + x_{it}\,\beta + v_{it}$

After estimating the individual levels of α_{it} the frontier position is identified in every time period:

(6) $\hat{\alpha}_t = \max_i \hat{\alpha}_{it}$

and

(7) $\hat{u}_{it} = \hat{\alpha}_t - \hat{\alpha}_{it}$

In order to estimate the α_{it}s, Cornwell et al. (1990) suggest to assume the same temporal structure of time variation for α_{it}:

(8) $\alpha_{it} = w_{it}\,\delta_i$

with:
$w_{it} = (1, t, t^2)$
δ_i = vector of temporal variation coefficients of individual intercepts

In this study, a linear temporal structure is imposed for w_{it}[3]:

[3] The term t^2 was dropped out from the error temporal structure because its presence in the translog specification prevented from performing specification tests for collinearity problems.

(9) $w_{it} = (1, t)$

that is:

(10) $\alpha_{it} = \delta_{i0} + \delta_{i1}\, t$

The equation (6) becomes:

(11) $y_{it} = w_{it}\, \delta_i + x_{it}\, \beta + v_{it}$

the coefficients of this equation are obtained in two steps: first the βs are estimated regressing ouput on x_{it} by GLS, then δ_i are estimated individually regressing the residuals, $y_{it} - x_{it}\hat{\beta}$, on t by OLS.

2.2. The variables

The set of variables[4] referred to the Italian provinces over the period 1980-90, used in the estimation of the production function, is illustrated in table 2. The sample is composed of 1045 observations: 95 provinces for 11 years. Descriptive statistics (table A.1) and correlation matrix (table A.2) are in the appendix A.1.

Tab. 2. Variables, sources, units of measure and acronyms

Variables	Sources	Units of measure	Acronyms
Output			
Gross saleable production deflated	ISTAT, Ist. Tagliacarne	million £ '80	GSPDF
Conventional inputs			
Utilized arable area	ISTAT	hectares	UAA
Intermediate inputs deflated	ISTAT, Ist. Tagliacarne	million £ '80	IIDF
Machinery	U.NA.CO.M.A.	horse power	MAC
Labor	ISTAT	annual working unit	LAB
Livestock	ISTAT	livestock unit	LIVE
Natural resources			
Utilised arable area corrected	ISTAT, MAF	hectares	UAAC
Rainfall	U. C. E. A.	millimetres	RAIN
Extensive/intensive farming			
Hilly and mountain land	ISTAT	%	HM
Protected crops	ISTAT	"	FMG
Irrigated land	ISTAT	"	IL
Productive composition			
Tree crop saleable production	Ist. Tagliacarne	"	TREE
Livestock saleable production	Ist. Tagliacarne	"	LIV
Territorial specification			
Dummy for Southern provinces		arabic numerals	DS
Time		"	T

<u>Output</u>

In this study it is followed the gross total productivity approach (Rutten, 1992; Trueblood, Ruttan, 1995) since output does not include feed grain and other self-produced inputs. Deficiency payments are excluded from production as well. Finally, in order to consider differences in output mixes, productive orientation is represented by two variables, LIV and TREE, respectively the percentages of saleable production accounted for by livestock outputs and tree crop products, according to Griliches's suggestion (1963). In this way, it is possible to differentiate among productive technologies associated to different production compositions.

[4]The basic data of this study are those used in Maietta, Viganò (1995) and they are the property of the C.S.R.E.A.M. (Portici, Naples).

The dependant variable is gross saleable agricultural production, built by using different statistical sources and deflated by appropriate price indices (Maietta, Marenco, Viganò, 1995). These latter were built by weighing the regional price index according to the provincial mix in herbaceous, tree crop and livestock saleable production. Within each of these groups, provincial crop mix could still differ; consequently, the measure of productive efficiency finally obtained also incorporates the effects of choosing crops with different prices within the three principal product groups. Note that even applying this correction, a province can appear more efficient because of saving in input use and/or of orienting the productive mix toward higher price crops within the herbaceous crops, the tree crops and the livestock productive activities.

Conventional inputs

Land is the area utilized for agriculture (UAA), it includes set-aside land. It has been corrected taking into account different soil fertility as described in the appendix A.2. The result is the variable UAAC.

Intermediate inputs are expressed in real terms. The value has been obtained by using regional price indices; therefore this variable is affected by aggregation problems as well.

Machinery is measured as a stock, that is the annual horse power available in each province. It has not been depreciated[5]. Fuel distributed for agricultural use has also been used as a proxy of the service flows from machinery but the fit it yielded was sistematically less higher than the stock variable.

Livestock is a stock variable measured in FADN equivalent unit, that is an adult animal[6]. As far as its inclusion in the production function as an input is concerned (Trueblood, 1991), one might say that this variable is not an output since it only includes adult animals of different species, present in each province at the end of that year and used for reproduction; consequently, it is a capital stock for the production of that year.

Labor is a flow variable expressed in FADN units, that is the number of equivalent fully-employed units in a year (2200 hours per unit). It does not include information about the quality of the agricultural labor.

Environmental variables used in the literature

The literature examined essentially suggests two indicators of environmental characteristics relevant for agricultural production: land quality and precipitation. Information on land quality was derived from a subjective evaluation (Bhattacharje,1955), from market prices (Griliches, 1963) and from a study on potential land yields over the world (Mundlak, Hellinghausen, 1982). From this latter, water avalaibilty, correlated to precipitation, was obtained as well; the same information seems to prevail in the index used in Frisvold, Ingram (1995).

[5]The only information available for taking into account the quality of the provincial machinery is the difference between the machines purchased in that year and the old ones.

[6]The coefficients used for the conversion in FADN units are: 1 for milk cows, 0.8 for other cows, 0.36 and 0.39 respectively for swines and sows, 0.14 for sheeps and goats (Cosentino, De Benedictis, 1979).

Time series of complex weather indices are those built by Oskam (1991) and Oskam, Reinhard (1992) for the Dutch agriculture over the period 1948-1989 detailed by crop, year and region.

Obviously, in order to represent land quality, a variable available for all the provinces was needed. Following the suggestion of other studies (Sotte, 1994)[7], official cereal yields were chosen as indicators of soil fertility since cereals are the only crops uniformly cultivated on the national soil.

The use of crop yields for efficiency measurement can be criticized since the yield possibly reflects the role of unaccounted inputs on technical efficiency of the productive units. In order to take into account this consideration and because of possible measurement errors affecting official yields, these latter were used not directly to weigh land area but after having identified groups of provinces (see appendix A.2), roughly similar in terms of soil conditions. The result of this procedure fitted better than the direct use of the official cereal yields as proxies of soil fertility.

Precipitation was selected as the main indicator of weather conditions for the Italian agricultural production since studies like that of Oskam are not avalaible for the Italian provinces[8]. The weather indicator RAIN is referred to the precipitation from October of the previous year to March of that year. Periods of different length were tried too, but with less satisfactory results. Basic data were monthly precipitation, stored in the National Agricultural Information System (S.I.A.N) and supplied by the Central Office of Agricultural Ecology (U.C.E.A.) of the Department of Agriculture. In particular, for every province the monthly datum has been estimated through the average of the precipitations observed in the meteorological stations selected as the most representative of the climate of that province.

This variable appears more suitable to summarize the most relevant aspect on agricultural production of the Mezzogiorno's climate which is drier than that of the rest of Italy. For the North and the Centre of Italy a humid vintage can be more dangerous given the different climatic conditions and the crops consequently cultivated (for example, winter cereals).

From a study conducted in 10 Northern Italian provinces over the period 1909-1980, precipitation seems not to influence wheat yield (Perini, 1993); therefore there should not be any correlation between the selected indicators of weather and land quality.

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[7] Sotte et al. (1994) measured agricultural productivity at a regional level by a DEA approach. They tried to measure land quality by the yield of barley, considered the cereal more representative of local fertility because it is less affected by technical innovations but they judged their attempts not satisfactory.

[8] Estimates of simple weather indices for the whole Italy over the period 1951-1991 are in Caiumi et al. (1995).

Other environmental variables

The two direct indicators of natural resources illustrated in the previous section seem not sufficient to summarize the quality of natural resources relevant for agricultural production, since an area good for cereal may be poor for other crops. Taking into account that agriculture is a multi-product industry, it seems necessary to add other variables at the same time representing the quality of land, relevant for other crops than cereals, and farming intensity. The variables introduced refer to the presence of irrigation, protected crops and mountain and hill land.

Irrigation is often used as a proxy of quality land in the estimation of agricultural production function both at an aggregate level (Mundlak, Hellinghausen,1982; Frisvold, Ingram, 1995) and at a microeconomic level (Ali, Chaudry, 1990; Battese, Coelli, 1995).

In this study, irrigation is expressed as the proportion of the operated land that is irrigated (IL) and it is intended as a proxy of intensive farming as well while the variable FMG, proportion of the operated land with flower and greenhouse crops, should pick up super-intensive farming. HM is simply the percentage of hill and mountain on total land: at the same time it indicates bad quality land composition and extensive farming. It does not show collinearity with the variable UAAC[9] (see table A.2).

2. 3. The specification of the production function

The functional form preferred in the literature on agricultural productivity is the Cobb-Douglas which is the most used both for estimates of aggregate agricultural production functions and for the analysis of farm efficiency (Battese, 1992; Bravo-Ureta, Pinheiro, 1993). This specification is adopted in eight of the ten studies on intercountry agricultural production functions compared by Trueblood (1991) and it is still used successively (Frisvold, Ingram, 1995) despite the critique of Lau, Yotopoulus (1989).

Therefore, this type of specification is first tried:

(12) $LogGSPDF_{it} = Log\alpha_t + \beta_1 LogIIDF_{it} + \beta_2 LogMAC_{it} + \beta_3 LogLAB_{it} + \beta_4 LogLIVE_{it} + \beta_5 LogUAAC_{it} + \beta_6 LogRAIN_{it} + \beta_7 HM + \beta_8 FMG + \beta_9 IL + \beta_{10} TREE + \beta_{11} LIV + \beta_{12} t + Lv_{it} - Lu_{it}$

Unfortunately, this specification does not fit well, therefore a translog functional form was tried as well.

The results of the regression estimates and of the comparison of efficiency levels with and without indicators of natural resource quality are given for both the specifications in the following sections.

[9]The variable HM should pick up the composition effect of different soil quality, the 'share' component, while UAAC should pick up the residual effect, land amount plus the 'fertility level' component.

3. Regression estimates with the indicators

Cobb-Douglas specification

The estimates of the stochastic production function coefficients derived from the regressions performed on the panel are shown in table 3.

Table 3 - GLS estimates of stochastic Cobb-Douglas production function (panel data) - Dependant variable log(GSPDF)

Variable	Coefficient	t-ratio
LUAAC	0.20	7.96
LIIDF	0.34	24.56
LLAB	0.20	10.99
LMAC	0.15	5.99
LLIVE	0.03	1.91
TREE	0.01	6.93
LIV	0.00	-1.02
LRAIN	0.03	3.46
HM	-0.002	-3.71
IL	0.004	3.54
FMG	0.13	8.25
T	0.03	16.39
Constant	1.19	6.74
R-squared	0.93	

Random Effects Model: v(i,t) = e(i,t) + u(i)
LM Test vs. model with regressors only = 1042
(1 df, prob value = 0.000000)
Fixed vs. Random Effects (Hausman) = 0.00010
(12 df, prob value = 1.000000)
Estimates: Var[e] = 0.013
Var[u] = 0.044

As one can see, adjusted R^2 and Student-t values are high and the signs are as expected. The Hausman test (Hsiao, 1986) largely supports the random effects model[10].

Among inputs, the most significant explanatory variables are intermediate inputs, labor, then land and machinery. Variables with good values of Student-t are also: super-intensive farming, FMG, productive specialisation, TREE, extensive farming in disadvantaged environment, HM, and intensive farming, IL. Livestock specialisation, LIV, is less significant probably because of collinearity with the variable livestock, LIVE.

With regard to the direct indicators of natural resource quality, RAIN seems to perform quite well.

The estimates of input coefficients are of the same size of those reported for intercountry samples (Kawagoe T., Hayami Y., Ruttan V., 1985; Lau, Yotopoulos,1989; Trueblood, 1991). With respect to the results for DC's country

[10]The critical value for the 5 percent significance level with 12 degrees of freedom is 21.

sample of Lau, Yotopoulos (1989), the partial output elasticities of land and labor, more traditional inputs, are lower for the Italian agriculture. Compared with those estimated by Griliches for the US regions (see table 1) they seems similar, probably because intranational data make it possible to differentiate productive technologies[11]. However these results are not directly comparable since they refer to different periods.

Finally, the scale returns from the estimated coefficients are diminishing since the sum of coefficients is 0.92. Probably this is due to the underestimated measurement of capital used in this study (it does not include building and land equipment because of data unavalaibility) since evidence suggests increasing returns to scale from conventional inputs for DC's (Trueblood, 1991).

The two regressions performed without the direct indicators of natural resources quality, UAAC and RAIN, and without these variables plus IL, FMG and HM, give quite similar results in terms of estimated coefficients. The most important effect on the input elasticity is related to land whose coefficient decreases to 0.09 and 0.08 respectively, while scale returns increase (in both the specifications they are equal to 0.96).

The Cobb-Douglas functional formulation has been verified by the battery of specification tests indicated by McGuirk et al. (1993). Unfortunately the results obtained (see tables A.4 and A.5 in the appendix A.3) reject this specification in all the alternative formulations tested.

Translog specification

This formulation is used to estimate aggregate agricultural production functions (Capalbo, 1988) and stochastic ones at regional level with panel data (Beeson, Husted, 1989); it has been proved to perform better than the Cobb-Douglas for samples with a large range of variation (Lau,Yotopoulos, 1989). This seems to be the case of the present sample, which is quite large, as can be seen from the maximum and the minimum values of the variables in table A.1.

The translog specification was tested on the set of conventional inputs plus the trend variable and accepted on the basis of the Reset2 test[12]. On this specification several restrictions were tested (see table A.6). Linear homogeneity is lost after adding the other variables.

From table 4, you can see that the partial output elasticities, evaluated at the sample input means, are generally quite good except for the coefficient close to zero of the intermediate inputs. However, the presence of environmental proxies improves its estimates and increases the value of scale returns from a value equal to 0.81 without all those variables to the value of 1.3 with all those variables.

Insignificant and unexpected signs for coefficient estimates with good overall explanatory power can be the consequence of multicollinearity.

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[11]Geographical groupings are preferred when examining aggregate production relationships (Haley, 1991).

[12]This gives a value of 0.88 for the F-statistics with degrees of freedom equal to 1 and 929, respectively for the numerator and the denominator; the correspondent critical value for the 5 percent significance level is 3.84.

Table 4. GLS estimates of stochastic translog production function

Variable	Coefficient						Output elasticity
	1-order	2-order					
		LUAAC	LIIDF	LLAB	LMAC	LLIVE	
LUAAC	-0,037	-0,042	-0,112	0,022	0,157	0,016	0,274
	(-0.14)	(-1.5)	(-3.9)	(0,75)	(4,12)	(0,52)	
LIIDF	-0,611		0,141	0,026	-0,137	0,077	0,002
	-3,00		(13,55)	(1,34)	(-4.58)	(4,10)	
LLAB	0,420			-0,022	0,003	-0,042	0,485
	(2,11)			(-1.82)	(0,12)	(-2.31)	
LMAC	0,456				-0,002	-0,058	0,298
	(1,50)				(-0.10)	(-2.46)	
LLIVE	0,227					-0,004	0,236
	(1,33)					(-0.31)	
TREE	0,006						
	(8,25)						
LIV	-0,005						
	(-6.54)						
LPRE	0,021						
	(2,61)						
MC	-0,001						
	(-2.7)						
IRR	0,001						
	(1,08)						
FOC	0,132						
	(8,54)						
AN	0,025						
	(12,84)						
Constant	4,512						
	(1,69)						
R-squared	0,955						
Scale returns	1,295						

Random Effects Model: v(i,t) = e(i,t) + u(i)
Lagrange Multiplier Test vs. model without group effect = 719
Estimates: Var[e] = 0,010
Var[u] = 0,032

However, individual parameters estimates are not particularly important in the measurement of efficiency since estimates of residuals are said to be influenced by the joint rather than the individual variable explanatory power (Trewin et al., 1995; Hallam, Machado, 1996).

The environmental proxies still perform well in this specification, except irrigation. Returns to scale increase respect to the Cobb-Douglas specification, as expected for flexible formulations (Kopp, Smith 1981).

4. Efficiency estimates with and without the indicators

Some descriptive statistics about the distribution of efficiency levels $\hat{e}_{it} = (1/\hat{u}_{it})$ estimated with the two specifications and the three sets of variables are reported in table 5.

Table. 5. Main parameters referred to the efficiency level distribution by functional specification

Parameter		CDwith	CDwithout	CDlandpre	TLwith	TLwithout	TLlandpre
average		0.54	0.38	0.37	0.63	0.56	0.56
median		0.53	0.34	0.35	0.65	0.56	0.57
minimum		0.31	0.17	0.18	0.36	0.30	0.30
range		0.69	0.83	0.82	0.64	0.70	0.70
var. coeff.		0.21	0.29	0.29	0.18	0.19	0.19
av. (1990-80)/1980		-0.09	-0.10	-0.11	-0.17	-0.13	-0.16
frontier observation		GE	IM	IM	GE	IM	IM
minimum obs.		GO,TS,CB	CB	PS,CB	TS,PS	PS	TS
North	*average*	0.72	0.44	0.44	0.71	0.61	0.61
	range	0.39	0.64	0.63	0.30	0.39	0.42
Centre	*average*	0.53	0.30	0.30	0.63	0.52	0.53
	range	0.05	0.02	0.02	0.12	0.06	0.07
South	*average*	0.57	0.41	0.41	0.78	0.66	0.67
	range	0.23	0.16	0.17	0.43	0.29	0.31

CD = Cobb-Douglas
TL = Translog
with = with UAAC, RAIN, HM, IL, FMG
without = without UAAC, RAIN, HM, IL, FMG
landpre = with UAAC, RAIN

First of all, the absence of the environmental variables in both the specifications generally decrease efficiency levels and increases value dispersion. These effects are exacerbated in case of mispecification: as expected, the translog specification always presents the highest values of average, median and minimum.

The proxies of natural resource quality indicated in literature do not perform so well since the average results obtained with the variables UAAC and RAIN are not significantly different from those obtained without. The position of the frontier is influenced by the variable omission but not by the functional mispecification. The contrary is true for the observations singled out as less efficient.

A flexible function seems to eliminate any territorial differential in the average impact of the environmental quality variables.

Table. 6. Deviation of efficiency levels obtained by TLwith and by other specifications

Parameter		CD-with	CD-without	CD-landpre	CDCD	TL-without	TL-landpre
absolute deviation							
	average	0,08	0,25	0,25	0,17	0,07	0,07
	maximum	0,30	0,51	0,50	0,46	0,27	0,23
	minimum	-0,17	-0,39	-0,39	-0,45	-0,39	-0,39
standard deviation		0,10	0,27	0,27	0,18	0,09	0,09
relative deviation							
	average	0,13	0,40	0,41	0,31	0,11	0,10
	maximum	0,36	0,57	0,57	0,51	0,27	0,24
	minimum	-0,24	-0,63	-0,63	-0,81	-0,63	-0,63
	st. dev.	0,16	0,42	0,42	0,33	0,14	0,13
absolute deviation							
North	*average*	-0,01	0,28	0,28	0,29	0,10	0,11
Centre	"	0,10	0,33	0,33	0,23	0,11	0,11
South	"	0,21	0,37	0,37	0,17	0,12	0,11
North	*maximum*	0,12	0,37	0,36	0,33	0,12	0,12
Centre	"	0,14	0,38	0,38	0,24	0,14	0,13
South	"	0,30	0,51	0,50	0,20	0,20	0,17
North	*minimum*	-0,14	0,19	0,19	0,25	0,08	0,10
Centre	"	0,07	0,28	0,28	0,21	0,09	0,08
South	"	0,11	0,24	0,24	0,13	0,05	0,05
standard deviation							
North		0,13	0,29	0,29	0,29	0,10	0,11
Centre		0,11	0,33	0,33	0,23	0,12	0,11
South		0,23	0,40	0,40	0,17	0,14	0,13
average relative deviation							
North		-0,02	0,39	0,39	0,40	0,14	0,15
Centre		0,16	0,52	0,52	0,43	0,18	0,17
South		0,25	0,47	0,47	0,29	0,14	0,13

CD = Cobb-Douglas
TL = Translog
CDCD = CDwith-CDwithout
with = with UAAC, RAIN, HM, IL, FMG
without = without UAAC, RAIN, HM, IL, FMG

landpre = with UAAC, RAIN

Table 6 reports efficiency level deviations from the results of the translog specification with all the environmental variables (TLwith) of those obtained by the others; only in the fourth column the deviation of the efficiency estimates, obtained by the Cobb-Douglas specification without environmental variables (CDwithout), is calculated from the results obtained by the Cobb-Douglas specification with all those variables (CDwith).

Three kinds of deviations are given: absolute, standard, defined as the average of the squared deviations, and the relative deviation respect with the TLwith values.

The underestimation due to the environmental variables is 14% on average, substantially due to the omission of the indirect proxies of natural resource quality in case of correct functional specification; it ligthly increases in case of functional mispecification. The effect of different sources of mispecification are not simply additive but cumulative since in case of variable omission and functional mispecification, the deviation from the correct estimate is 42% on average and can reach peaks of 63%. It is not possible to observe any specific territorial behaviour.

5. Concluding remarks

Indicators of natural resource quality affecting agricultural production have been introduced as non-conventional inputs in the specification of the aggregate production function estimated for the Italian provinces during the '80s. The measurement of the productive efficiency in agriculture perfomed with and without these indicators brings to the following conclusions:

1. the indicators of environmental conditions suggested in literature, land quality and water availability, do not affect efficiency levels very much; on the other hand, the proxies of farming intensity affect efficiency estimates to a greater extent, especially in case of incorrect functional specification;
2. the functional mispecification alone causes an average deviation from the level obtained with the correct specification close to that obtained in the case of variable omission.

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Appendix A1

Table A.1. Descriptive statistics of the variables

Variable	Mean	Std. Dev.	Skew.	Kurt.	Minimum	Maximum
GSPDF	465060	321720	1.1	4.0	10800	1732000
IIDF	138670	122610	2.0	7.3	2109	701700
UAA	154290	104800	1.6	6.6	1591	599100
UAAC	177440	110680	1.3	5.2	2908	599100
MAC	937470	631310	0.9	3.5	22820	3513000
LAB	23365	16732	1.5	5.9	404	99460
LIVE	51331	51249	2.0	7.6	516	294600
TREE	23	18	1.0	3.2	0	79
LIV	39	22	0.5	2.4	19	92
RAIN	454	258	4.2	43.0	46	3769
HM	70	32	-0.8	2.4	0	100
IL	16	17	2.2	7.7	0	87
FMG	0.3	0.8	0.0	6.3	0	10

Table A2. Correlation matrix of the variables used

Variable	GSPDF	IIDF	UAA	UAAC	MAC	LAB	LIVE	TREE	LIV	RAIN	HM	IL	FMG	DS	T
GSPDF	1														
IIDF	0.82	1													
UAA	0.42	0.24	1												
UAAC	0.47	0.26	0.96	1											
MAC	0.72	0.77	0.34	0.35	1										
LAB	0.61	0.32	0.45	0.44	0.34	1									
LIVE	0.49	0.70	0.51	0.47	0.51	0.26	1								
TREE	0.17	-0.23	0.18	0.22	-0.09	0.38	-0.28	1							
LIV	-0.01	0.44	-0.02	-0.09	0.19	-0.25	0.58	-0.64	1						
RAIN	-0.10	-0.11	0.01	0.03	-0.20	0.09	-0.05	-0.04	-0.03	1					
HM	-0.49	-0.50	0.00	-0.11	-0.49	-0.15	-0.24	0.07	-0.04	0.07	1				
IL	0.47	0.61	-0.07	-0.02	0.42	0.13	0.42	-0.23	0.25	-0.08	-0.65	1			
FMG	0.01	-0.08	-0.26	-0.25	-0.19	0.00	-0.16	-0.11	-0.21	-0.03	0.04	0.05	1		
DS	0.06	-0.27	0.43	0.44	-0.30	0.38	-0.07	0.52	-0.44	0.08	0.20	-0.25	-0.08	1	
T	0.21	0.14	-0.04	-0.03	0.18	-0.12	-0.04	0.00	-0.07	-0.17	-0.01	0.05	0.05	0.00	1

Appendix A2

A.2. Land quality indices

Cereal (except corn) yields, used in this study to weigh agricultural land amount, were calculated by the Department of Agriculture for the mountain, hill and plain land of each province through an average of the three years chosen over a five-year period (vintages from 1986-87 to 1990-91) after excluding the two extreme observations (MAF, 1992).

These data were used to identify groups of provinces similar in terms of soil conditions (table A.3). Roughly speaking these groups include Northern provinces, Centre's ones and Southern ones.

More precisely, among Northern provinces from Torino to Ravenna, the following sub-groups are isolated:

1.1. high mountain (mountain of Torino, Novara, Aosta, Sondrio, Bolzano);
1.2. Liguria's mountain and hill zones,
1.3. Trieste;
1.4. all the other Northern provinces.

Among the other provinces, the sub-groups are:

2.1. provinces from Forlì to Isernia;
2.2.1. marginal mountain (Frosinone, Caserta, L'Aquila);
2.2.2. Salerno, Potenza, Matera, Cosenza, Reggio Calabria, Ragusa, Nuoro, Oristano;
2.3. from Foggia to all the other Southern provinces, the three altitude zones were considerd equivalent in terms of cereal yields.

Plain land of the groups 1.* (except Trieste), 2.1, 2.2 and all the land of the group 2.3 has been considered equally fertile with a weight equal to one.

Then, among the groups 1.*, the average yield for group altitude is divided by the plain average yield of the group 1.4. With regard to the groups 2.1 and 2.2, the average yield of mountain and hill zones is divided by the plain average yield of its own group; for the provinces of subgroup 2.2.1, their average mountain yield and their own individual hill yields are divided by the average plain yield of the whole group 2.2.

Tab. A.3. - Soil fertility weights by altitude and province

Group	Provinces	Soil fertility weights		
		Mountain	**Hill**	**Plain**
1.1	Torino, Novara, Aosta, Sondrio, Bolzano	0.40	0.86	1.00
1.2	Liguria's	0.49	0.49	–
1.3	Trieste	–	–	0.55
1.4	Vercelli, Cuneo, Asti, Alessandria, Lombardia's, Trento, Veneto's, Udine, Gorizia, Pordenone	0.71	0.86	1.00
2.1	Forlì, Marche's, Toscana's, Umbria's, Viterbo, Rieti, Roma, Latina, Benevento, Avellino, Napoli, Teramo, Pescara, Chieti, Molise's	0.78	0.85	1.00
2.2.1	Frosinone	0.54	0.54	1.00
2.2.1	Caserta	0.54	0.85	1.00
2.2.1	L'Aquila	0.54	-	-
2.2.2	Salerno, Basilicata's, Cosenza, Reggio Calabria, Ragusa, Nuoro, Oristano	0.66	0.75	1.00
2.3	Puglia's, Catanzaro, Trapani, Palermo, Agrigento, Messina, Enna, Caltanisetta, Catania, Siracusa, Sassari, Cagliari	1.00	1.00	1.00

Source: Maietta, Marenco, Viganò, 1995

Appendix A3

Table A.4. Joint mispecification testing on the Cobb-Douglas formulation

Sources of mispecification	Variable set	F-values	df num.	df den.
	Conditional mean			
a) spatial parameter instability	1. South*, Ysquared, u [-1]	1543	9	934
	2. South*	247	7	936
	3. Ysquared,	105	1	941
		39	1	941
b) temporal parameter instability	1.Trend**, Ysquared, u[-1]	1763	9	933
	2. Trend**	729	7	935
	3. Ysquared,	108	1	941
	4. u [-1]	36	1	941
	Conditional variance			
a) spatial parameter instabiltiy	1. South***, Ysquared, u [-1]squared	19594	8	933
	2. South***	14622	6	934
	3. Ysquared,	collinearity		
	4. u [-1]squared	2399	1	941
b) temporal parameter instabiltiy	1.Trend**, Ysquared, u[-1]squared	23127	8	933
	2. Trend**	17970	8	935
	3. Ysquared,	2441	1	941
	4. u [-1]squared	2386	1	941

*conventional inputs, TREE and LIV, variables multiplied by DS
**conventional inputs, TREE and LIV variables multiplied by T
***conventional inputs and TREE variables multiplied by DS

Table A.5. Results of the individual mispecification testing on the Cobb-Douglas formulation

Specification		F-values*	
	Variable	Reset2	Reset3
conventional inputs		117	67
plus			
	TREE, LIV,T	132	65
conventional inputs multiplied by			
"	TREE and LIV	137	114
"	DS	122	119
"	D84	131	56
"	T	23	85
GSP[-1], conventional inputs[-1]		99	51

*degrees of freedom are 1 for Reset2 and 2 for Reset3, those for the denominators go from 932 to 941

Table A.6. Linear restrictions tested on the translog formulation

Restriction	F	d.f. num.	d.f. den.	LM	LR	W	d.f.
on conventional inputs plus t							
1. Cobb-Douglas	29	15	929	337	408	449	15
2. quadratic	7.9	10	929	81	84	88	10
3. CES						118	10
4. homogeneity						5.01	5
5. linear homogeneity						8.2*	6
on conventional inputs plus t, TREE, LIV, RAIN,HM, IL,FMG							
6. CES						164	10
7. homogeneity						4.55	5
8. linear homogeneity						13.5*	6

* the critical value for the 5 percent level of significance is 12.6