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YIELD RISK IN WHEAT PRODUCTION: A POLICY STUDY FOR THE ALENTEJO OF PORTUGAL

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The Portuguese wheat sector has been protected from international competition since the end of the last century. However, with the Wheat Campaign, begun in 1929 by the then-new Salazar government, protection acquired greater significance and scope. Output-price policy attempted to satisfy both consumes (through an adequate supply of cheap bread) and producers (through the support of producer prices). Government purchases were used to maintain producer prices. Prices were set according to production costs and announced at planting time. These prices were usually above CIF import prices.

By 1960, the price support policy had begun to fail. Farmers were confronted with increases in labor costs due to the African wars, increased domestic industrial employment opportunities, and emigration to the industrialized parts of Europe. Because wheat prices were stable and labor costs were rising, «the net effect was falling revenues for Southern farms, which were then confronted with the task of transforming their operations through mechanization» (Avillez, Finan, and Josling, 1988).

The 1974 revolution brought land reform. Southern «latifúndios» were occupied by landless workers, and by 1976 comprehensive land reform was in place. Subsequently, wheat production declined substantially, and producer prices were below world prices until 1978 (Josling and Tangermann, 1987). After that, the degree of protection from world competition increased for wheat and other cereals. The continuation of prices supported above the world market levels and large subsidies aggravated the public deficit. Partly in response to this problem, input subsidies were eliminated in 1983 although high producer prices for cereals were maintained.

The Alentejo is the leading wheat-producing region in Portugal even though it is constrained by water availability and poor soil quality (very poor soils account for approximately 73 % of total arable land). Variability in annual yields is because of the weather, with frequent occurrences of excessive rain or winter drought which severely affect wheat production (Fox, 1987).

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This study first explores the hypothesis that Portuguese wheat price policies stabilized wheat prices but not wheat farmers' incomes. It is found that income variability from wheat production in the Alentejo has been greater than for the rest of the country.

Weather variability is hypothesized as a major source of income variability in the Alentejo so a wheat supply model with plantings and yields as functions of prices and rainfall is estimated to establish this link. Since Portugal's accession to the European Community (EC) in January 1986, price policy for agricultural products has been largely dictated by the Common Agricultural Policy (CAP), despite some Portuguese autonomy during the transition period. But EC-price policies will do little to reduce income variability, and yield risk will continue to constrain farmers' willingness to invest in wheat production. Portuguese decision makers have the authority to implement a crop or a multiple-crop insurance program. Such a program may have a positive impact on wheat production by stabilizing output returns to farmers. The costs of providing a crop insurance program for wheat in the Alentejo are estimated by simulating the financial performance of such a program.

Price stabilization and income stabilization

To determine the extent to which Portuguese wheat price policies have stabilized income, the variance of income per hectare is decomposed into variances of prices and yields. The impacts of farm price policies can be characterized as reducing price variability or income variability, if the respective variances would have been more under a regime of «world» wheat prices. The logarithm of total revenue is monotonically related to total revenue, but the price and quantity terms are additive in that:

$$\log\ TR = \log\ p + \log\ y \qquad \mathbf{(1)}$$

were TR is total revenue per hectare, p represents price, and y represents yield per hectare [1]. Differencing **(1)** focuses on year-to-year changes, and gives:

$$\Delta\log\ TR = \Delta\log\ p + \Delta\log\ y \qquad \mathbf{(2)}$$

where Δx representes $x_t - x_{t-1}$. Applying the variance to both side of **(2)** gives

$$\mathrm{Var}(\Delta\log\ TR) = \mathrm{Var}(\Delta\log\ p) + \mathrm{Var}(\Delta\log\ y) + 2\ \mathrm{Cov}(\Delta\log\ p,\ \Delta\log\ y) \qquad \mathbf{(3)}$$

which is used to isolate the impact of price and yield variations on total revenue per hectare. In **(3)**, each variance measures deviations about the average

(1) In the case of the multicrop farm, it is necessary to take account of the covariance between the returns of different crops. Letting i subscript be the ith crop, the variance of total revenue is:

$$\mathrm{Var}(TR) = \sum_i \mathrm{Var}(R_i) + 2 \sum_i \sum_{i<j} \mathrm{Cov}(R_i, R_j)$$

for each variable. But each variable is a differenced logarithmic quantity so the average for the variable represents the average rate of growth [i.e., $d\log x = dx/x$ and $\text{avg}(d\log x) = \text{avg}(dx/x)$]. Thus **(3)** first isolates the long term rate of increase (or decrease) in the price and yield variables, and then measures the variation of price and yield about the long term trends.

The variance decomposition in **(3)** was done for the nation as a whole and for the Alentejo using annual time series data from 1965 to 1984. These data were taken from *Estatísticas Agrícolas,* Portugese National Institute of Statistics (INE), and from the World Bank (Avillez, Finan and Josling, 1988). The World Bank data were derived from INE data, which implies consistency among the data. In addition, the world wheat price can be substituted for the domestic wheat price to assess the effects of domestic wheat price policy on price and income variability. The world wheat price is taken from Avillez, Finan, and Josling (1988).

The decomposition of the variance of total revenue per hectare is shown in table 1. The results indicate that both the Alentejo and Portuguese yields increased by about one percent per year on average while prices, measured in constant escudos, fell by about half a percent per year on average. Table 1 then accounts for price and yield variations after these long term trends are removed. This table shows that yield deviations from long term trends are primarily responsible for revenue deviations from long term trends. For example consider the Alentejo with yields valued at domestic prices. Here, 90.7 % and 5.0 % of the deviation of revenue per hectare from its long term trend was caused by yield and price deviations, respectively. Furthermore, yield variation appears to be the primary cause of revenue variation regardless of the price assumption used (domestic or world prices) but the relative importance of price variation increases when world prices are used. This table also shows that the national yield is less variable than Alentejo yield increases (76.2 % of 0.021830 for the nation as opposed to 90.7 % of 0.025376 for the Alentejo).

The conclusion from table 1 is that over the study period, Portuguese price policy was successful at insulating domestic prices from world price instability. Domestic prices were less volatile than world prices and as a result, revenues were somewhat stabilized. This indicates the effectiveness of price stabilization policy as a component of income stabilization. The existence of yield risk in wheat production in the Alentejo remains substantial and eliminating or reducing price variability still leaves substantial revenue variability.

Wheat supply response

Because weather variability in the Alentejo may be a major potential source of yield variability, wheat supply estimation must consider economic as well as weather variables. A wheat supply model for the Alentejo, with equations for planted area and yield is estimated for the 1965-1984 time-period in order to examine the significance of weather in causing yield variability. Following Nerlove (1979), it is assumed that adjustment occurs in the area planted but constraints permit only a fraction of the desired adjustment to be realized during the short run. This formulation reflects the constraints of crop rotation. In the Alentejo, wheat land is fallowed during the summer for good soils, while a one or two year rotation of wheat-barley or oats-fallow is used on other soils (Firmino, 1979). Area planted with wheat is assumed to be influenced by the current wheat-to-barley price ratio. This procedure mitigates the multicollinearity that results from the price policy common to all cereal crops.

Wheat production also depends on rainfall and the exclusion of rainfall from the model could cause a specification problem. Average rainfall during the growing season is included in the yield equation. Lahiri and Roy (1985) point out that rainfall should be specified as a non-linear relationship to account for the detrimental impact of droughts as well as floods, but because of multicollinearity between the linear and the quadratic terms, the linear specification was used. The gain from reduced variances of the retained variables offsets the loss from a less correct model specification. Data for rainfall in 1970 were not published for any stations in the Alentejo so it was assumed that rainfall in Alentejo for 1970 was equal to the sample average for rainfall.

The model of the desired total area planted with wheat is:

$$\log(AREA^*_t) = a_0 + a_1 \log(PW/PB)_t + a_2 D_t + e_t \qquad \textbf{(4)}$$

where $AREA^*_t$ is the desired planted area in period t, $(PW/PB)_t$ is the ratio of wheat to barley prices received by farmers in period t, D_t is the qualitative variable that represents the effect of land reform that occurred after the 1974 revolution (2) and e_t is the disturbance term for period t. Following Nerlove (1979), area planted is assumed to be a function of the desired area in that:

$$\log(AREA_t) - \log(AREA_{t-1}) = \alpha\{\log(AREA^*_t) - \log(AREA_{t-1})\} \qquad \textbf{(5)}$$

where α is the coefficient of adjustment. Substituing **(4)** into **(5)**, solving for $\log(AREA_t)$, and estimating the result by ordinary least squares *(OLS)* gives (3):

$$\log(AREA_t) = \underset{(.829)}{8.170} + \underset{(.138)}{0.165} \log(PW/PB)_t - \underset{(.142)}{0.406} \log(AREA_{t-1}) - \underset{(.0608)}{0.521} D_t$$

Durbin $H = .552$ $\qquad R^2 = 0.867$ $\qquad F(3.15) = 32.48$

These results suggest the area planted to wheat responds positively (in the short run) to the price of wheat and negatively to the price of barley, its chief competitive crop. The short run price elasticity of 0.165 is of the correct sign but is not highly significant as the probability of a larger t is equal to 0.249. The negative coefficient on lagged area results from crop rotation constraints and implies that small plantings follow large plantings due to these constraints. The combination of the positive price elasticity and the negative coefficient on lagged area indicates that the long run response to a price increase will encompass an initial increase in plantings but increased plantings

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(2) A dummy variable was used to incorporate the effect of the land reform. It is assigned a value of zero until 1976 and a value of one after 1976. This variable captures the fact that land reform caused significant decreases in the area devoted to wheat after 1976.

(3) Standard errors are reported in parentheses in this and subsequent regressions.

will result in decreased plantings in subsequent years as crop rotation constraints take effect. The coefficient on the dummy variable indicates that land reform caused a significant reduction in the are a planted to wheat. The Durbin *H* statistic follows a normal (0.1) distribution so serial correlation of the residuals does not appear to be a problem. The entire regression equation is significant at beyond the one percent level of significance.

The yield of wheat per hectare *(YLD)* is estimated as:

$$\log(YLD_t) = -79.473 - .00159\ RWS_t + .0443\ TIME_t - .558\ D_t + .204 \log(PW_t/PF_t)$$
$$(34.40) \quad (.000804) \quad (.0175) \quad (.219) \quad (.276) \qquad \textbf{(7)}$$
$$DH = 2.83 \qquad R^2 = .511 \qquad F(4.15) = 3.93$$

where RWS_t is the average winter and spring rainfall (December to May of year t) for agricultural stations in the Alentejo, $TIME_t$ is a time-trend variable set equal to year t, PF_t is the average price farmers paid for 18-36-0 fertilizer in the growing period t, and PW_t is the price of wheat in period t.

According to these results, winter and spring rainfall is significant at beyond the ten percent level in explaining yields. The positive coefficient on *TIME* indicate an average annual rate of yield increase of 4.43 %. The average annual rate of yield increase of 1 % reported in table 1 incorporates both the average 4.43 % per year increase in yields and the effect of land reform (D_t) which is associated with a 56 % yield reduction. Both the effect of technological change *(TIME)* and land reform are significant at beyond the five percent level of significance. Finally, the coefficient on the ratio of wheat to fertilizer prices indicates that the elasticity of yields to the price of wheat is 0.204 and the elasticity of yields with respect to the price of fertilizer is – 0.204. The Durbin-Watson statistic indicates that serial correlations is not a problem and the regression is significant at beyond the five percent level.

The importance of the effects of rainfall can be compared to the importance of the other effects in equation **(7)**. The probability of a larger *F* for rainfall is 0.066, while the probability of a larger *F* associated with the hypothesis that the effects of *TIME*, *D* and log(*PW*/*PF*) are all zero is .112. The conclusion is that rainfall is at least as significant as the other effects (as a group) in explaining yield variation. In summary, these results indicate that rainfall variability contributes substantially to yield variability, which subsequently contributes to income variability in the Alentejo.

Crop insurance

Risk is one reason that many governments intervene directly in agricultural product and factor markets. Portuguese wheat farmers face a variety of risks, such as weather that make their incomes variable. These risks are of interest to policy-makers because fluctuations in farm incomes result in welfare losses for the rural community if farmers are risk averse. The purpose of crop insurance is to stabilize income so that the farmer can pay debts and meet essential living costs each year (Hazell, Bassoco, and Arcia, 1986).

The Portuguese government could intervene in the wheat sector by providing an all-risk insurance program. In general, farmers in developed and developing countries have been unwilling to pay the full cost of all-risk crop insurance and, thus, most of the all-risk programs remain in the public sector.

All insurers must contend with moral hazard and adverse selection. Moral hazard arises when farmers become less agressive about avoiding damages because of the availability of insurance compensation. A common solution to this problem is "coinsurance" in which part of the risk is borne by the insured. Adverse selection arises when contracts are written with identical premia and indemnities. The insurer cannot determine the risks being insured on an individual basis so that if the insurer offers a policy that is strongly subscribed by the higher risk groups, the firm can expect losses. In practice, compulsory insurance is a solution to the adverse selection problem, but this encourages moral hazard unless a progressive premium structure is adopted. Because of these costs, private firms have little or no incentive to provide all-risk crop insurance. Furthermore, substantial externalities are associated with agricultural risks because the incidence of crop failure will affect not only farmers and their creditors directly, but also a vast cross section of society. These factors may prompt governments to provide crop insurance.

The welfare economics of crop yield-insurance must be addressed to understand the issues of government-subsidized crop insurance. Contrary to the general case (Siamwalla and Valdés, 1986), if demand is perfectly elastic, farmers will capture all the benefits from the insurance. If a subsidy is given, there will be further benefits to farmers. However, nothing can be said *a priori* about the expected sign of the social gains from a subsidized insurance plan (Trindade, 1990).

Siamwalla and Valdés argue that subidies can be justified only during the initial phase of an insurance program. Subidies can also be justified for small-scale farmers, who are more vulnerable and unable to pay the full price of insurance. Subsidies might also be desired if the public has reason to support farmer incomes, such as compensation for the adverse consequences of Portugal's accession to the EC. In the following section the costs of a hypothetical wheat insurance program for the Alentejo region will be estimated and compared to historical wheat sector subsidization levels.

The use of homogeneous areas rather than individual farms as the basic unit of insurance coverage solves the adverse selection problem of an insurance plan (Ahsan, 1985). The area should be as small as possible in order to accurately account for deviations of the actual yields from average but as large as possible to reduce administrative costs and the costs of collecting weather, soil, and crop yield data. The greater the agroclimatic homogeneity of the area, the lower should be the yield variation within the area. Indemnities can then be based on each year's deviation from the average yield for the area. A drawback of using homogeneous areas is that many farmers will obtain yields different from the average for the specified area.

Expected costs of a wheat insurance program

In this analysis, the Alentejo is treated as a homogeneous area. A hypothetical wheat insurance program which provides coverage against multiple yield risks is simulated. Natural weather-related disasters, such as hail and drought are covered under this type of insurance. The crop insurance fund for the region is represented as:

$$R_t = (1 + i)\ R_{t-1} + P_t - L_t - A_t \qquad \textbf{(8)}$$

where R_t represents ending reserves for year t, i represents the rate of return on the investment of reserves, P_t represents premiums collected in year t, L_t represents losses indemnified in yeart t, and A_t represents the cost of administering the fund in year t. It is assumed that the premiums collected are based on a constant charge per hectare planted (i.e., $P_t = ca_t$ with a_t = planted area), that the costs of administering the fund are related to the size of the fund and the premiums collected (i.e., $A_t = \phi P_t + \delta R_{t-1}$), and that indemnities are paid if the yield for the area (y_t) is less than some proportion, Θ, of the long-term average yield for the area. The yield shortfall is valued at prevailing prices (p_t) so:

$$L_t = \begin{cases} a_t p_t (\Theta \bar{y} - y_t) & \text{if } y_t \leq \Theta \bar{y} \\ 0 & \text{otherwise} \end{cases}$$

Substituting $P_t = ca_t$ and $A_t = \phi P_t + \delta R_{t-1}$ into **(8)** and employing continuous substitution for beginning reserves gives:

$$R_t = (1 + i - \delta)^t\ R_0 + c(1 - \phi)\ \Sigma_{\tau=0}^{t-1}\ a_{t-\tau}\ (1 + i - \delta^\tau - \Sigma_{\tau=0}^{t-1}\ L_{t-\tau}\ (1 + i - \delta)^\tau \qquad \textbf{(9)}$$

One way to impose a long run equilibrium on the fund, is for the fund at the end of the sample period to be equal to the fund at the beginning of the sample period (i.e $R_0 = R_T$). Using **(9)** to express R_T, imposing $R_0 = R_T$, and solving for c (the uniform premium per hectare planted), gives:

$$c = \frac{R_0[1 - (1 + i - \delta)^T] + \Sigma_{\tau=0}^{T-1}\ L_{T-\tau}\ (1 + i - \delta)^\tau}{(1 - \phi)\ \Sigma_{\tau=0}^{T-1}\ a_{T-\tau}\ (1 + i - \delta)^\tau} \qquad \textbf{(10)}$$

The fund is capitalized at the outset (R_0) so that it remains solvent over the sample period. This is done by setting R_0 so that at least 100 Ω percent of initial reserves are available for contingencies throughout the sample period. A bisection search is used to solve for R_0 such that min $R_t = \Omega\ R_0$ ([4]).

([4]) A bisection search consists of evaluating the objective function at two values of the independent variable. One value of the independent variable, x^+, is selected so that the objective functions is too large, while the other value of the independent variable x^-, gives an objective function value that is too small. The objective function is then evaluated at x^0, the midpoint of the interval between x^+ and x^-. If the objective function is too large at x^0, x^0 replaces x^+, otherwise x^0 replaces x^-. The process is repeated until a solution is found to the objective function, Convergence on the solution value is assured because with each iteration, the interval between x^+ and x^- is halved.

The simulation is forward looking in the sense that it reflects results as if Portugal was a member of the EC. Portugal has been a member of the EC since 1986 and EC policy will govern prices received in the future by Portuguese wheat farmers. Therefore, EC wheat prices for the 1965-1984 period were used to value Portugese wheat production. EC wheat prices were calculated using CAP prices expressed in units of account (UA) up to 1979; after that time, they were expressed in terms of European Currency Units, (ECUSs) [AgraEurope (London), Ltd., 21-1-1989].

Several scenarios were used to simulate the effects of insurance on income variability. One scenario, shown in table 2, assumes that an indemnity was paid when the actual yield is less than 80 % of the average yield ($\Theta = .80$). The indemnity payment is calculated as the difference between the actual yield and 80 % of the average yield valued at the prevailing EC price, measured in constant (1980) escudos. On a per hectare basis, insurance with an 80 % yield guarantee would have reduced the standard deviation of total revenue per hectare by 439.7 esc/ha, which is about 3.2 % of the uninsured mean revenue. In this scenario, indemnities would have been paid in 1966, 1969, 1977, and 1978, the years when yields were less than 80 % of the average yield. If yields are guarantee at 90 % of the average yield, indemnities would have been paid in 1966, 1969, 1970, 1977, 1978, 1979, 1981, and 1983. And, if the yield guarantee was 70 % of the average yield, indemnities would have been paid in 1966, 1969, and 1978. These simple calculations show that wheat insurance reduces income variability, since it increases the level of income realized in «bad» years. Wheat insurance partially compensates the losses associated with weather uncertainties in the Alentejo.

Ideally, agricultural insurance eliminates income variability and causes farmers to behave as if they were risk neutral. Agricultural insurance is potentially an efficient risk- sharing mechanism (Nelson and Loehman, 1987), but the feasibility of programs depends on transaction costs. It is assumed that 40 % of the premium must cover administrative costs (Ahsan, p 36). Hence, $\phi = .4$ (5).

The initial reserve is required to face possible initial yield losses. It is set so that at least 10 % of initial reserves are always in the fund ($\Omega = .10$). The premium is assumed to be a constant per hectare and depends on the level of yield losses to be indemnified.

Table 3 shows the results of simulating the insurance fund over the 1965-1984 sample period under the above assumptions. The table is parameterized on the level of the yield guarantee and the net rate of return ($i - \delta$) earned by the fund. This table shows that as the level of the yield guarantee goes up, the premium increases and as the net rate of return on invested reserves increase, the lower the average level of the reserves needs to be. Note that in all cases, the mimimum reserves are equal to 10 % of the initial reserves. The fund was

(5) The soluiton of **(10)** with $\phi = .4$, denoted as c^0, is easily converted to solutions which assume other values of ϕ (e.g., ϕ^*) with $.6c^0/(1 - \phi^*)$. Thus, the interested reader can easily explore other assumptions about administrative costs.

set up to be perpetuating so that the initial investment is the only social outlay required to implement the plan. This outlay can be compared to the cost required for the historical continuous subsidization of the crop.

To examine the relative costs of the provision of insurance under each scenario cost to the wheat farmers under historical output price policies, total direct subsidies were estimated as the difference beteween actual producer prices and "world" prices. This subsidy amounted to 1,185.46 million 1980 esc. per year over the 1865 through 1984 sample period. This annual subsidy is slightly more than the one-time amount required to capitalize an insurance fund with a 70 % yield guarantee, slightly less than the one-time amount required to capitalize an insurance fund with a 80 % yield guarantee, and about half the amount required to capitalize an insurance fund with a 90 % yield gurantee. Therefore, the implementation of an insurance plan does not seem expensive relative to alternative support programs.

Conclusion

This study had three sequentially-related objectives. The first objective was to determine if Portuguese wheat price policy had contributed to stabilization of the wheat price and/or a stabilization of wheat farmers' incomes. It was found that wheat price policy had focused on price stabilization rather than income stabilization. Yield instability was found to be substantial, especially in the Alentejo region. The second objective was to determine the cause of such yield variability. Several regressions were done for area and yield equations. It was found that rainfall is relevant in explaining variations in wheat yields. Third, an all-risk insurance policy was considered as the policy that could stabilize income to farmers, «because price risks are controlled by Portuguese and EC policies, but yield risks continue to limit farmers' willingness to invest» (Fox, 1987). It was emphasized that insurance reduces the variability of income and increases the level of income realized in "bad" years. However, the implementation costs and the delineation of "homogeneous areas" remain crucial to the success of any insurance plan.

Year	Planted area (1000 ha)	EC-price (1980 = 1) (esc./kg)	Alentejo yield (kg/ha)	Total value (mill. esc.)	Yield shortfall (a) (kg/ha)	Value w/Ins. (mill. esc.)
1979	205.4	11.99	921.00	2 268.2		2 268.2
1980	257.3	12.18	1 253.25	3 927.6		3 927.6
1981	248.4	10.40	967.75	2 500.0		2 500.0
1982	259.5	9.65	1 180.25	2 955.6		2 955.6
1983	240.7	10.09	991.25	2 407.4		2 407.4
1984	206.2	8.88	1 653.00	3 026.7		3 026.8
Average	301.27	12.49	1 105.56	4 252.09	33.90	4 320.63
Std. dev.	64.32	2.32	272.30	1 811.26	86.77	1 759.12

(a) Yield guarantee is 884.45 kg/ha = 80 % of 1105.56 kg/ha.

TABLE 3

Alentejo wheat crop insurance fund simulation, 1965-1984

Year guarantee	Net ROI $i-\delta$ (percentage)	Premium (percentage of uninsured revenue)	Fund levels			
			Beginning	Maximum	Minimum	Average
70 %	0	2.69	917.62	1 001.0	91.76	613.8
	2	2.23	904.31	991.7	90.43	578.1
	4	1.84	888.68	981.2	88.87	543.1
	6	1.49	871.13	969.6	87.11	509.5
	8	1.19	852.07	957.1	85.21	477.6
80 %	0	5.45	1 446.38	1 615.5	144.64	833.8
	2	4.77	1 459.34	1 636.6	145.93	865.5
	4	4.13	1 463.36	1 650.0	146.34	842.8
	6	3.53	1 458.97	1 656.0	145.90	816.5
	8	2.98	1 447.05	1 655.3	144.71	787.7
90 %	0	10.14	2 118.90	2 433.5	211.89	1 314.1
	2	9.12	2 142.03	2 467.8	214.20	1 300.7
	4	8.13	2 151.70	2 490.1	215.17	1 279.7
	6	7.19	2 148.42	2 500.5	214.84	1 252.4
	8	6.31	2 133.29	2 499.8	213.33	1 220.0

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