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Estimating Supply Response Function for Wheat: A Case Study

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التقدير الكمي لعامل استجابة عرض القمح: دراسة حالة

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خلاصة: بالرغم من الدعم الذي تقدمه الحكومة الأردنية لشراء القمح من المزارعين بسعر أعلى من السعر العالمي إلا أن إنتاج القمح في محافظة اربد بالأردن ظل متدنيا. يعاني القطاع الزراعي في الأردن من مخاطر في الإنتاج والأسعار لاعتماده على الأمطار في زراعة القمح. وقد تم تقدير استجابة العرض للقمح المنتج في محافظة اربد باستخدام نموذج نيرلوف. وكانت المساحات المزروعة العامل الرئيسي في دالة استجابة العرض. بالإضافة إلى العوامل المؤثرة الأخرى مثل المساحة المزروعة بمحصول القمح بالدونم في السنة الحالية والسنة السابقة والأسعار الموزونة بالرقم القياسي لتكاليف المعيشة ومعامل التفتت الحيازي في السنة السابقة ومخاطر الإنتاج وكمية الأمطار بالمليمتر خلال الشهور الأولى من الموسم (أكتوبر ونوفمبر وديسمبر). وتوصلت الدراسة إلى إن التفتت الحيازي هو أحد أهم العوامل المؤسسية التي تؤثر بصورة رئيسية على انخفاض المساحة المزروعة بالقمح. وبما أن نظام الميراث هو العامل الرئيسي المؤثر على التفتت الحيازي فإنه يتحتم على صانعي القرار توجيه الجهود للتخفيف من آثار هذه الظاهرة. كما أوصت الدراسة بأن تتبنى الحكومة سعر العرض اعتمادا على الرقم القياسي لتكاليف المعيشة ليعكس السعر الحقيقي الذي يؤثر على استجابة العرض. وكان معامل التعديل الجزئي منخفضا (اقل من ١) وهذا يعني إن المزارعين يحتاجون إلى اكثر من سنة لتعديل المساحة المزروعة استنادا إلى العوامل المؤثرة على دالة استجابة العرض. وأخيرا وجد إن المزارعين هم من النوع متعادلي المخاطرة ويعتمدون في اتخاذ قراراتهم على معدل هطول الأمطار ومناطق هطولها.

ABSTRACT: To increase wheat production, governments can subsidize wheat farmers by purchasing their produce at a price higher than the world price. This policy did not succeed in increasing wheat production in the Irbid Governorate of Jordan, our case study area. The agricultural sector in the study area was characterized by risk in production and prices. In our study, the supply response function based on the Nerlovian Model was estimated for wheat produced in Irbid Governorate. Wheat area, in the model, was the dependent variable in the supply response function. The independent variables were: wheat planted area in Dunums in the current and previous year respectively, the weighted price of wheat in the previous year deflated by the Consumer Price Index (CPI), the holding fragmentation coefficient in the previous year, the yield risk, and the amount of rain in millimeters during the early months of the season (October, November, and December). The study reached the following conclusions: Firstly, holdings fragmentation was the major factor that negatively affects wheat production. Since the heritage system is the main factor that affects holding fragmentation, the policy makers need to find a way that can decrease this effect. Secondly, lagged weighted prices were found more suitable than the current weighted prices from an economic and statical point of view. Thirdly, the partial adjustment coefficient was low (i.e. less than one), which means that the farmers need more than one year to change their producing habits. Finally, the farmers were found to be risk-neutral, because their decisions depend mainly on the level and distribution of rainfall during the rainy season.

Keywords: wheat production, Nerlovian Model, subsidy, holding fragmentation coefficient.

The annual growth of international wheat production was 2.1% during the period 1970-1999 (FAO, 1999). The major developed countries, USA (2.5%), France (2.3%), Canada (3.4%), and Australia (1.3%), were responsible for this increase in production. In 1999, these countries contributed to the total wheat production by 11, 6, 4, and 3 %, respectively. On the other hand, wheat production in the developing countries, where the

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TABLE 1

Agro-climatic regions in Jordan.

Zone	Annual Rainfall (mm)	Area (1000 ha)	Percent
Semi-Desert	< 200	7270	81.4
Arid	200-300	920	10.3
Semi-Arid	300-400	130	1.5
Semi-Humid	> 400	110	1.2
Jordan Valley	100-350 (irrigated)	500	5.6

(Royal Scientific Society, 1995).

TABLE 2

Wheat subsidy in Jordan during 1990-1997.

Year	Prices of Imported Wheat* (JD/ton)	Subsidized Prices of Local Wheat** (JD/Ton)	Value of Subsidy (JD/ton)	Quantity Purchased by the Govt** (thousand tons)	Total Value of Wheat Subsidy (thousand JD)
1990	102.6	142	39.4	32.38	1275.77
1991	74.7	147	72.3	35.59	2573.15
1992	100.6	147	46.4	71.79	3331.05
1993	118.5	147	28.5	53.71	1530.73
1994	109.4	147	37.6	37.65	1415.64
1995	118.9	165	46.1	51.30	2364.93
1996	182.7	200	17.3	29.47	509.83
1997	128.0	200	72.0	21.21	1527.12

(Department of Statistics,"Annual External Trade" Several Issues. Amman, Jordan; Ministry of Planning (unpublished data), Amman, Jordan. 1998).

self-sufficiency ratio is very low, showed a negative growth during the same period. Jordan was no exception, since the annual production growth of wheat during the same period was -2.4%. Accordingly, it imported large quantities of wheat annually. During 1995-1996, 480 thousand tons were imported. This increased to 728 thousand tons during 1997-1998 (Department of Statistics, DOS, 1999).

The land area of Jordan (Table 1) is about 89.3 million dunums (One dunum = 0.1 hectare); only five million dunums are cultivated. Most of this cultivated land is in the highlands. Rainfed agriculture occupies about 4.5 million dunums, and the rest is irrigated.

Agricultural activities in Jordan are hampered by a limited water supply for irrigation. However, since the eighties, major investments in farming technologies, especially drip irrigation and plastic house farming, have made a vast improvement in irrigation system efficiency and recycling of treated waste water.

Due to the variable topographic features rainfall distribution varies considerably with location. Annual rainfall intensities range from 600 mm in the northwest to less than 200 mm in the eastern and southern deserts which form about 91% of the surface area. Jordan's average rainfall amounts to about 8425 MCM/year, varying between 6235 and 10630 MCM/year. Approximately 92.2% of the rainfall evaporates, while the rest flows in rivers and wadis (valleys) as flood flows and recharge to groundwater. Groundwater recharge amounts to approximately 5.4% of the total rainfall volume, while surface water accounts for approximately 2.4% (Belbisi, 1992).

Land area is divided into five zones: semi-desert, arid, semi-arid, semi-humid and the Jordan Valley, which have widely differing agricultural potential (Table 1).

Wheat is considered the most important strategic crop. It occupies about 60% of the planted area, and constitutes about 68% of field crops production. To increase wheat production, the Government, through the Ministry of Supply, subsidized wheat growers by purchasing their produce at a price higher than the world price (Table 2). This policy, which was terminated in 1998, did not succeed in increasing wheat production. In the Irbid study area, wheat production actually decreased by 6.9% (Figure 1).

Wheat is produced in Jordan in different agro-climatic zones (Table 1); each zone is characterized by a variety of factors affecting production. For this reason an almost homogeneous area was chosen for conducting our study. This area, the Irbid Governorate, is located in the northern part of the country where wheat area and production constituted 17 and 24%, respectively during the period 1995-1998 (DOS, 1999).

Self-sufficiency of wheat in Jordan ranged between 3% in 1999 (a drought year) and 33% in 1989 (a wet year) (Table 3).

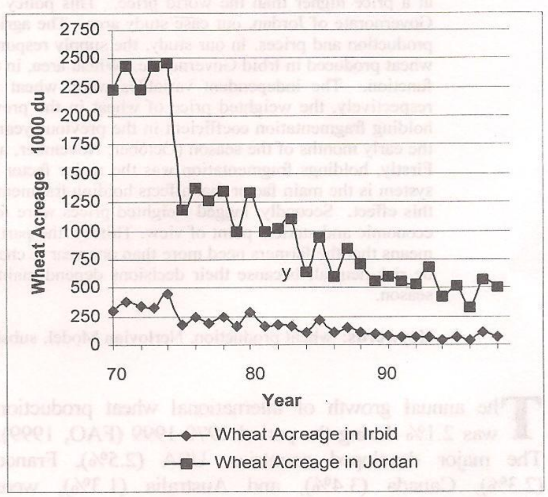

Figure 1. Wheat planted area in Jordan and Irbid during 1970-1998. (Department of Statistics, 1999).

TABLE 3

Wheat acreage (thousand dunums) in Irbid and in Jordan.

Year	Wheat Acreage in Irbid	Wheat Acreage in Jordan
1970	294.0	2228.4
1971	384.3	2439.4
1972	338.1	2236.7
1973	327.5	2441.8
1974	445.1	2462.0
1975	172.1	1183.3
1976	246.6	1369.5
1977	196.5	1264.5
1978	243.9	1345.7
1979	162.1	989.6
1980	287.8	1331.8
1981	169.2	991.5
1982	174.4	1019.6
1983	162.7	1106.6
1984	103.8	642.3
1985	215.5	943.6
1986	109.4	594.4
1987	151.4	843.2
1988	107.3	701.8
1989	97.3	562.1
1990	88.1	605.3
1991	71.0	564.7
1992	63.1	534.1
1993	66.4	679.2
1994	44.8	424.5
1995	67.9	512.3
1996	46.6	329.3
1997	107.5	568.9
1998	70.1	504.6

(Department of Statistics, 1998).

Research Methodology

THE SUPPLY RESPONSE MODEL: In our study, the supply response function will be estimated. This function takes care of lagged affects such as planted area and the price of the commodity in the previous period.

Sadoulet and Janvry (1995) noted that a central problem in the estimation of supply response equation is that producers respond to expected as opposed to actual prices. In addition, they argued that the observed quantities may differ from the desired ones because of adjustment lags in the reallocation of variable factors. The Lagged Models, which include the Polynomial Distributed and Autoregressive Models, will be used to estimate the supply response function for wheat produced in Irbid Governorate. This model enables us to estimate the Partial Adjustment Coefficient, which helps in finding the speed of farmers' response to changes in areas and wheat prices. This will help decision makers to choose the best policy that could increase wheat production, and thus, increase the self-sufficiency ratio of this important product.

Usually, the quantity produced is considered to be the dependent variable, while the other variables are exogenous. In our study, the planted area was taken as the dependent variable. The rationale for this is that farmers planting decisions follow two steps. In the first step they decide on the planted area, then they decide on the level of input application (Houk and Ghalagher, 1976). In addition, the use of area as proxy to production depends on the fact that the farmer has full control on the planted area decision. The expected production however, depends on factors that cannot be predicted such as weather.

The direct relationship between planted area and production can be explained through Figure 2. The movement from P_1 to P_2 causes an increase in the acreage of the crop from A_1 to A_2. This will be followed by an increase in production from Q_1 to Q_2 (Ghatak and Ingercent, 1984). The general supply response function is given by:

$$AW_t = f(AW_{t-1}, PW_{t-1}, HFC_{t-1}, Risk, R_{ONDt}) \quad (1)$$

where: AW_t and AW_{t-1} are planted area in Dunums in the current and previous year, respectively; PW_{t-1} is the wholesale price of wheat in the previous year deflated by the Consumer Price Index (CPI); HFC_{t-1} is holding fragmentation coefficient in the previous year; Risk is the productivity risk; R_{ONDt} is the amount of rain in millimeters during the early months of the season (October, November and December). The rationale for choosing the variables in Equation 1 is explained in the following sections.

WHOLESALE PRICE OF WHEAT: According to economic theory, prices play an important role in deciding what to produce, i.e. how to produce and for whom to produce.

The Cobbweb model is used to explain the unstable performance of many agricultural commodity

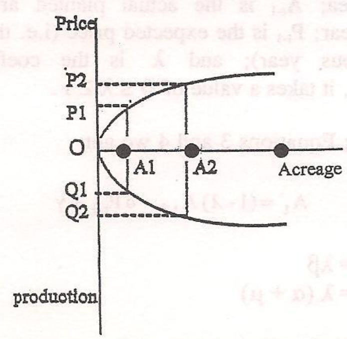

Figure 2. The relationship between production and acreage.

markets. The solution of this model gives the time path of current prices as a function of time. A dynamic market equilibrium is achieved if prices stabilize, i.e. if $P_t = P_{t-1}$ as $t \to \infty$ (Sadoulet and Janvry, 1995). This model copes with the Naïve Expectation Model for prices. It is a good indicator for decision-making followed by the wheat farmers. Equation (2) shows the expected price in the current year as a function of the price in the previous year.

$$P_t^* = P_{t-1} \quad (2)$$

where: P^*_t is the expected price in the current year and P_{t-1} is the price in the previous year.

In our research, wholesale prices of wheat (i.e. prices paid to producers) deflated by the Consumer Price Index were used to take the level of inflation into consideration. The price in the previous year was included in the analysis model. The real prices were not used because they were fixed by the government for a long period of time.

PLANTED AREA IN DUNUMS IN THE PREVIOUS YEAR: The planted area in the last year is considered an important indicator to the partial adjustment process that farmers face when taking their production decisions. Nerlove and Addison (1958) were the first to include this variable in the supply response functions where they used static and dynamic models for this purpose. Taking this variable into consideration in the dynamic models will help in estimating the long-run elasticity of supply, while using the static models will generate the short-run elasticity of supply.

The Nerlovean Model can be written as follows:

$$A_t^* = \alpha + \beta P_{t-1} + U_t \quad (3)$$

$$A_t - A_{t-1} = \lambda (A_t^* - A_{t-1}) \quad (4)$$

where: A_t^* is the desired planted area; A_t is the actual planted area; A_{t-1} is the actual planted area in the previous year; P_{t-1} is the expected price (i.e. the price in the previous year); and λ is the coefficient of adjustment, it takes a value of $0 \le \lambda \ge 1$.

Combining Equations 3 and 4 we get:

$$A_t = (1-\lambda) A_{t-1} + \delta P_{t-1} + \gamma \quad (5)$$

where: $\delta = \lambda\beta$

$\gamma = \lambda(\alpha + \mu)$

To estimate the long-run elasticity of supply from this function, the following equation is used:

$$\varepsilon_1 = \varepsilon_s / \lambda \quad = \delta * (P_{t-1} / A_t). \quad (6)$$

where: ε_1 is the elasticity of supply in the long-run and ε_s is the elasticity of supply in the short-run.

YIELD RISK: The agricultural sector is characterized by risk in production and prices. This is mainly due to the effect of climate on the production of crops grown in rainfed areas. Wheat is a rainfed product, so the level and distribution of rain affects its productivity. This kind of risk is called "Yield Risk".

The risk variable can be calculated according to the "Gallagher Method"(Gallagher, 1978).

$$\text{Y.Risk} = \frac{[YW_{t-1} - 0.5(YW_{t-2} + YW_{t-3})]^2}{0.5(YW_{t-2} + YW_{t-3})} \quad (7)$$

where: Y. Risk is the productivity risk; YW_{t-1} is the wheat yield in the previous year; YW_{t-2} is the wheat yield before two years; and YW_{t-3} is the wheat yield before three years.

PRECIPITATION LEVEL: Wheat is planted in rainfed areas. The farmers in different locations use two methods of planting, the first is early planting, i.e. late in October, where they plant their land before the rain starts. This practice is carried in the arid and semi-arid regions. In the second method, farmers plant their fields after the first acceptable rain; this occurs at the second half of November and the first half of December.

Wheat farmers in the semi-wet study area, follow the second method. It was found that the most important period that affects wheat production are the months of October, November, and December. So the cumulative amount of precipitation was considered as the rain variable.

HOLDINGS FRAGMENTATION: This variable is included in the Supply Response Model for wheat in Irbid because small farmers (i.e. who own small parcels of land) either leave the land uncultivated or produce for home consumption. The major constraint in wheat production in Irbid Governorate was found to be holding fragmentation, where the Islamic inheritance law causes this fragmentation, and since the land law which does not allow to register the holding to each heir separately if ownership is less than 0.1 hectare, the owners of the land have to cultivate it collectively. In turn, this causes the farmers to leave their land uncultivated, or plant fruit trees, mainly olives, instead of field crops, and thus the area planted with wheat will continue to decrease.

$$L_n A_t = \ln \alpha + \beta_1 \ln A_{t-1} + \beta_2 \ln P_{t-1} + \beta_3 \ln HFC_{t-1} + \beta_4 \ln RISK + \beta_5 \ln R_{NDt} + \varepsilon_t \quad (9)$$

The variables included in Equation 9 were defined in the previous section, and the estimated coefficients of this function are summarized in Table 6.

The coefficient of determination ($\bar{R}^2$) shows that the variables in the equation explain about 74% of the variations wheat area changes, while there are other variables not accounted for, explains about 26% of the variation of wheat area.

Since Equation 9 includes the lagged variable of the planted area as an independent variable, the ordinary D.W-test could not be used to estimate the presence of autocorrelation in this model. The modified D.W-test, identified as "h- test" which follows the normal distribution functions, was therefore used. The equation for the h-test is as follows:

$$h = 1 - \frac{D.W}{2} \sqrt{\frac{N}{1 - N[v(\hat{\beta})]}} \quad (10)$$

where: h is the modified D.W-test; D.W. is the calculated D.W. value; N is the number of observations; and $v(\hat{\beta})$ is the variance of the variable A_{t-1}.

The calculated (h) value was found to be -1.4. The tabulated value at the confidence level of 0.05 is ± 1.645, this means that the autocorrelation does not exist in Equation 10.

The sign of the area planted in the previous year was found positive and its value is 0.467, which is between one and zero. Thus, the partial adjustment coefficient, see Equation 5, equals $1-\beta_1 = 0.533$. This means that the farmers are slow in changing the planted areas. It took more than one year to do this change. The slow change in planted area with wheat could be explained by the fact that the farmers in this area produce mainly for their own consumption, which is emphasized through the significance of the holdings fragmentation coefficient in the estimated model.

The coefficient of the deflated price was found to be 0.856 and positive. This coefficient is considered as the short-run elasticity of supply, were a change in this price by 10% causes a change of planted area by 8.56%, i.e. inelastic supply function. On the other hand, the calculated long-run elasticity of supply was calculated as 0.856/0.533 =1.606, which means that the long-run supply function is elastic, as expected. So the decision-makers should offer higher prices to reach the desired level of production in the long run.

TABLE 6

Estimated coefficients of supply response function.

Explanatory Variables	Estimated Parameters	t-test Values
Constant	3.170	0.768
AW_{t-1}	0.467	2.778*
PW_{t-1}	0.856	1.724**
HFC_{t-1}	-1.146	-2.511*
Risk	-0.016	-0.521
$R_{OND\,t}$	0.243	1.930**
$\bar{R}^2$	0.740	
F-Statistics	16.176	
D.W	2.247	
h-test	-1.427	
λ	0.533	

**Significant at the 0.05 level.*
*** Significant at the 0.10 level*

Holding fragmentation constituted the major factor that decreases the wheat planted area, since it was found -1.146, which means that an increase of this coefficient by 10% will decrease wheat area by 11.46%.

In addition, the effect of the level of precipitation during the early period of the rain season was found to be low (about 0.243), although the sign of the coefficient copes with the economic logic. This result can be partially explained by the fact that some farmers plant wheat before the rain starts, and in some years rain was not distributed evenly in the rainy season.

Conclusions

From the above analysis we can reach the following conclusions:

Holdings fragmentation was the major factor that affects negatively on wheat production in Irbid Governorate. Since the heritage system is the main factor that affects holding fragmentation, policy makers have to find a way, or laws that can decrease this effect. The problem here is that the heritage system has a religious background, which makes it difficult to find a solution. We recommend the establishment of producing cooperatives, which gather the farmers in one entity and cultivate the land collectively. Another solution could be renting the land to large companies that can cultivate the land in a more efficient way.

Lagged deflated prices were found more suitable than the current prices from an economic and statically point of view. Using the Consumer Price Index as a deflator was found to be appropriate due to the fact that wheat producers act as consumers, not as producers. This is explained by the existence of smallholdings that produce only for family consumption rather than commercial production.

The partial adjustment coefficient was low, which means that the farmers need more than one year to change their producing habits.

The farmers were found risk-neutral, because they depend mainly on the level and distribution of rainfall.

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