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Induced Technical Change in Agricultural Development in Saudi Arabia

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Abstract. The rapid rate of growth in Saudi agricultural development was a result of technolgy changes. Thus, three alternative hypotheses are proposed in this paper to explain the induced technical change in production growth. The results indicate a bias toward mechanical rather than biological technology regardless of factor endowments. This is consistent with Saudi agricultural development where capital and land are abundant but labor is relatively scarce. Thus, agricultural production in Saudi Arabia should take an advantage of capital intensive methods.

Introduction

The Kingdom of Saudi Arabia has experienced a rapid rate of growth in the agricultural sector during the last two decades. Special attention has been given to agricultural development, throughout the facilities and services provided to the Saudi farmers, to achieve a higher level of basic food self-sufficiency to avoid political and socioeconomic crisis. As a result of these facilities, services, and incentives, private investors and corporations were attracted to invest in the agricultural sector. Hence, the number of existing agricultural specialized projects have increased in different activities.

Agricultural specialized projects, using large scale production system, high-yielding varieties, and large quantities of fertilizer, took advantage of price support and import subsidies to increase agircultural and livestock production.

Accordingly, total crop area has increased from 7.3 million donums in 1982 to 13.5 million donums in 1990 or about 85% increase. Area of all cereal crops has increased up to 9.7 million donums in 1990 which represents about 72% out of the total crop area, while production of all cereals has increased from .87 million ton in 1982 to 4.1 million tons in 1990 or about 362% increase. Due to the especial concern given to wheat, area and production of wheat have increased from 2.5 million donums, .82 million tons in 1982 to 7.5 million donums, 3.5 million tons in 1990 or 200, 335% increase respectively. Wheat yield per donum has reached 700 Kg. Total vegetables have increased from .7 million donum in 1982 to 1.04 million donums in 1990 or about 49% increase. Total area of fodder crops has increased from 1.4 million donums in 1986 to 1.8 million donums in 1990 or about 29% increase. Total area and production of citrus have increased from 15 thousand donums, 8 thousand tons in 1982 to 49 thousand donums, 35 thousand tons in 1990 or about 227, 302% increase, respectively. Total area of fruits has increased from 77 thousand donums in 1986 to 82 thousand donums in 1990 or about 6.5% increase [1].

The continuous growth in dairy specialized projects caused quantity of raw milk production to increase from 97 thousand tons in 1983 to 284 thousand tons in 1990 or about 193% increase. Number of eggs and broilers produced by specialized projects have increased to 2060 million eggs, 208 million broilers in 1990, respectively [1].

Importing food commodities have decreased from 11,529 million tons in 1984 to 6,563 million tons in 1988 or about 43% decrease, while the quantity of local agriculture production has increased by 2.7 million tons or about 40% increase for the same period [2].

An advanced biological and mechanical technology was applied to accomplish the rapid rate of agricultural productivity growth along with relative scarcity of resources. In fact, Saudi Arabia has declared self-sufficiency in wheat, dairy products, eggs production, and with increase in other grain and livestock production. Hence agriculture contribution to the GNP has increase to 8% at the end of the fourth development plan (1985/1990) [3].

This drastic change in the output was a result of technology changes, therefore, three alternative hypotheses are proposed in this paper to explain the more rapid growth in Saudi agricultural production. Due to the relative scarcity in some important agricultural resources such as land and labor, it is hypothesized that:

1. Land becomes increasingly scarce as a result of boosting output so that a new technology will be biased toward land-saving direction,

2. During the period of study, there was a sizable transfer of agricultural labor to the nonagricultural sectors, accompanied by the rapid mechanization of agricul-

tural production and more positive attitudes toward technology and managerial improvements, and also associated with large number of agricultural specialized projects, thus; labor becomes increasingly scarce and a new technology will be biased in a labor-saving direction, and

3. Change in the land-labor ratio has been induced by changes in relative factor endowments as a result of the drastic change in output accompanied by large changes in relative factor use.

The major objective of this paper is to test these hypotheses by empirically investigating the relative factor endowments use in the Saudi agricultural production.

Review of Literature

Fan and Ruttan [4] stated that the importance of technical change as a central element in modern economic growth has been accepted as almost self-evident since at least the middle of the 19th century. But it was not until the 1950s that economists began to develop the methodology to measure the contribution of technical change to economic growth. The primary focus of the early studies on technical change was simply to measure the contribution of technical change, relative to conventional inputs, to growth in output. Major effort was devoted to attempts to partition growth in output per unit of total input among conventional factors of production and a set of non-conventional factors including advances in knowledge and improvements in the quality of physical and human capital. Technical change was viewed as a response to the economic opportunities resulting from advances in scientific and technical knowledge that were, themselves, exogenous to the economic system. In the mid-1960s, however, increasingly serious efforts have been made to explore the influence of economic forces on the rate and direction of technical change. Models in which the rate of technical change was induced by growth in demand were employed by Griliches [5] in studies of technical change in agriculture and by Schmookler [6,p.332] to explore differential rates of technical change among industries.

The initial tests of the induced technical change model in agriculture by Hayami and Ruttan [7,p.111-135, 8] demonstrated that differences and changes in relative factor prices offered a powerful explanation for differences in the direction of technical change in Japan and the United States of America during the period 1880-1960. In Japan advances in biological technology facilitated the substitution of chemical inputs (such as fertilizer) for land. In the U.S. advances in mechanical technology facilitated the substitution of mechanical technology (such as mechanized motive power) for labor.

Salem and Sherif [9] identify some indicatores of technical change in the Saudi agriculture sector. They used a historic data over the period 1972-1989 on both the input and output sides. An econometric attempt is made, utilizing the production function approach, to capture technical change which is disembodied in factors of production. Different functional forms have been estimated utilizing the techniques of non-linear and ridge regression. They conclude that the increasing returns to scale is due to an elastic labor input with respect to the output. They recommend more work be done to increase the efficiency of the human resources in order to preserve agriculture development in the Kingdom.

Mansour [10] has measured and evaluated the economic performance of the Saudi agricultural sector over the period 1975-1987. He demonstrates the role of agriculture in developing the Saudi economy and the efficiency of agricultural sector in using its own resources. The results show a high level of economies of scale, a high level of capital productivity, and remarkable low level of labor productivity.

Chambers and Just [11] developed a method to estimate flexible representation of joint and nonjoint technologies. The method can discriminate between true and apparent nonjointness and can be used to estimate variable input allocations in the case of nonjointness. Depending on specification, linear methods can be used to estimate the technology with statistical efficiency. The paper answers several specific questions and corrects some misunderstandings that have arisen in the agricultural economics literature about specific characterization of agricultural technologies.

Empirical work about the output bias of technological change in postwar Japanese agriculture was reported by Kuroda [12]. The study tests the hypothesis that technological change in postwar Japanese agriculture was biased towards livestock production. A multioutput translog cost function was estimated for the 1958-1984 period in which results are consistent with the hypothesis. Furthermore, changes in the composition of crop and livestock pfoduction had significant impacts on relative factor uses.

Additional study provided a nonparametric analysis of U.S. agricultural technology and technical change under profit-maximizing or cost-minimizing behavior was done by Chavas and Cox [13]. Based on annual data for 1948-83, various separability hypotheses concerning the aggregate production function for U.S. agriculture are investigated. Their conclusion is that profit maximization without technical change is rejected for most time periods and output specifications evaluated. This is interpreted as strong evidence of technical change in U.S. agriculture. In contrast, the nonparametric results support the hypothesis of Hicks-neutral technical change.

Materials and Methods

A time series data over the period 1975-1989 is used in this paper. The data is obtained from different periodicals published by the Ministry of Agriculture and Water [1], the Ministry of Finance and National Economy [14], the Ministry of Planning [3], and other official agencies such as the FAO publications [15].

Econometrics and statistics are the principal procedures used to explain the induced technology change in the Saudi Agricultural development. The empirical tests of the induced technical change model for the Saudi Agricultural development based on three hypotheses generated from the model are presented as follows:

$$F/A = f(L/A, M/A, T, U_1) \quad \text{.... (1)}$$

$$M/L = f(A/L, F/L, T, U_2) \quad \text{.... (2)}$$

$$A/L = f(F/A, M/L, T, U_3) \quad \text{.... (3)}$$

where:

F = Fertilizer input (ton), expressed in logs,
A = Agricultural land (ha), expressed in logs,
L = Agricultural labor, expressed in logs,
M = machinery input (number of tractors used), expressed in logs,
T = time trend, expressed in logs, and
U = disturbance term.

Results and Discussion

The two stage least squares (2SLS) technique is employed for the estimation. Labor-land, machinery-land, fertilizer-labor ratios, and time trend are used as instrument variables for the simultaneous equations in the induced technical change model. The Praio-Winsten method is also used to avoid the autocorrelation in the disturbance term.

The results are presented in the Table. The model satisfies standard tests, regression F-ratios are significant at the 1% level for equations (1) and (3), and at the 5% level for equation (2). The coffecient estimates are significant at standard significance levels except fertilizer-land ratio. Durbin-Watson and correlation matrix indicate the absence of serial correlation in the residuals and multicollinearity among the explanatory variables.

Table. Technical change model estimation

Equation		C	L/A	M/A	A/L	F/L	F/A	M/L	T	R^2	D.W	F-test
(1)	F/A =	-7.45	0.215*	0.192					3.18			
		(-11.6)**	(2.63)**	(2.25)***					(8.18)**	0.989	2.69	213.3**
(2)	M/L =	-6.39			1.31*	-0.484						
		(-6.1)**			(1.83)***	(-0.987)***				0.528	1.005	3.74***
(3)	A/L =	-11.6					-1.39*	0.489*	5.585			
		(-4.13)**					(-.3.38)**	(4.7)**	(5.62)**	0.886	2.39	17.53**

The numbers in parentheses are t-test values.
*denotes sign is consistent with hypothesis.
** indicates signficance at 1% level, *** indicates significance at 5% level, and
*** indicates significance at 20% level.

Equation (1) presents a test of the hypothesis that if land becomes increasingly scarce new technology will be biased in a land-saving direction. To test this hypothesis, fertilizer-land ratio is regressed against labor-land ratio. To be consistent with the hypothesis the labor-land coefficient must be positive. Machinery-land ratio and time trend are also included in the regression without specifying expected signs. The sign of the coefficient is consistent with the hypothesis which indicates that biological technology has been induced by changes in the labor-land ratio. Thus, biological technology (fertilizer-land ratio) is expected to increase by .21% and .19% for a 1% increase in the labor-land and machinery-land ratios, respectively.

Equation (2) presents a test of the hypothesis that if labor becomes increasingly scarce new technology will be biased in a labor-saving direction. The machinery-labor ratio is regressed against land-labor and fertilizer-labor ratios in order to test this hypothesis. To be consistent with the hypothesis the coefficient of the land-labor ratio has to be positive. The sign of the coefficient of the land-labor ratio is consistent with the hypothesis. Thus, the test is consistent with the case of Saudi Arabia where the labor is the least intensive. So it could be claimed that the mechanical technology has been induced by changes in the land-labor ratio. The elasticity of substitution between mechanical technology and land-labor ratio is estimated to be 1.3 which indicates with increasing the growth rate of Saudi agricultural development, there is a high potential for substituting mechanical technology (capital intensive) for labor.

Equation (3) presents a test of the hypothesis that changes in the land-labor ratio itself have been induced by changes in relative factor endowments. To test this hypothesis, the land-labor ratio regressed against fertilizer-land and machinery-labor ratios. To be consistent with the hypothesis the fertilizer-land coefficient must be negative and the machinery-labor coefficient ratio must be positive. The signs of the fertilizer-land and machinery-labor coefficients are consistent with the hypothesis.

The major findings of the empirical analysis are as follows: land-labor ratio is elastic, where labor-land ratio is inelastic. These findings indicate that with expanding the output production in Saudi agriculture, there is a bias toward mechanical rather than biological technical change regardless of factor endowments. These findings support the results of: Al-Homudi [16], who found the elasticity of substitution between capital and labor to be 1.5; Salem anbd Sherif [9], who found high elasticity of labor; and Mansour [10], who estimated the capital-output ratio to be .89 which indicate a high efficiency of capital used in agricultural sector. The results are consistent with Saudi agricultural development, where capital and land are abundant but labor is relatively scarce. Subsequently, resources in Saudi Arabia have a high potential for substituting capital for labor efficiently, and agricultural production should take an advantage of capital intensive techniques. Finally, a suggestion for future research should be focused on biased technology for different agricultural activities such as bias toward expanding livestock production.

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التغيرات التقنية المصاحبة للتنمية الزراعية بالمملكة العربية السعودية

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ملخص البحث. حققت المملكة العربية السعودية تقدمًا كبيرًا في تنمية القطاع الزراعي زاد على أثرها الإنتاج المحلي في معظم الأنشطة الزراعية مما أدى إلى ارتفاع نسبة إسهام القطاع الزراعي في الناتج المحلي حيث بلغت حوالي ٨٪ في نهاية الخطة الرابعة (١٩٨٥م - ١٩٩٠م). ويهدف هذا البحث إلى دراسة تأثير التغيرات التقنية على تنمية القطاع الزراعي وذلك باختبار ثلاث فرضيات:

الفرضية الأولى: تتأثر ندرة عنصر الأرض طرديًا مع التنمية الزراعية، وبالتالي فإن التغيرات التقنية سوف تحافظ على استخدام عنصر الأرض.

الفرضية الثانية: تتأثر ندرة عنصر العمل الزراعي طرديًا مع التنمية الزراعية، وبالتالي فإن التغيرات التقنية سوف تحافظ على استخدام عنصر العمل.

الفرضية الثالثة: تؤدي التنمية الزراعية إلى التغير النسبي في عوامل الإنتاج المستخدمة وبالتالي تغير نسبة عنصر الأرض إلى العمل.

لقد تم استخدام طريقة المربعات الصغرى على مرحلتين (2SLS) باستخدام بيانات السلاسل الزمنية للفترة ٧٥-١٩٨٩م، ويتضح تطابق النتائج مع الفرضيات السابقة. كما أوضحت النتائج أن مرونة نسبة عنصر الأرض إلى العمل تساوي ١,٣ مما يدل على أن زيادة التوسع في الإنتاج الزراعي في المملكة سوف تؤدي إلى إحلال رأس المال بدلاً من العمل. وتشير نتائج الدراسة إلى زيادة استخدام التقنية الميكانيكية (والتي تتطلب كثافة رأسمالية) أكثر من البيولوجية عند التوسع في الإنتاج الزراعي.

وتتفق النتائج مع ظروف المملكة العربية السعودية حيث إنها تتميز بوفرة نسبية لكل من عنصر رأس المال والأرض وندرة عنصر العمل، ومن ثم فإن موارد المملكة تسمح بإمكانية إحلال رأس المال بكفاءة محل العمل وبالتالي فإن الإنتاج الزراعي في المملكة يمكن أن يستغل طبقًا لأساليب إنتاج كثيفة رأس المال.