International Journal of Agricultural Science and Research Volume 3, Number 1, Winter 2012 (Serial #6)

Effects of R&D spending and Spill-Over on Agricultural TFP in Iran

Solmaz Shamsadini[1], Saeed Yazdani[2], Reza Moghaddasi[3]

[1]*Ph.D. student, Department of Agricultural Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran.*

[2]*Professor, Department of Agricultural Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran.*

[3]*Assistant Professor, Department of Agricultural Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran.*

Received: July, 13, 2013 *Accepted: May, 1, 2014*

ABSTRACT:

Investing in research and development spending (R&D) affects total factor productivity (TFP). Recently new theories of economic growth have emphasized the relationship between R&D and TFP and also identified a number of channels through which a country's R&D affects TFP of its trade partner. This study seeks to estimate the effect of agricultural R&D and education spending and some other factors on agricultural TFP in Iran during 1971 to 2011. Agricultural TFP is calculated using Kendrick Index and the model is estimated by OLS method using E-Views 7.0.
All explaining variables in the model (right-hand variables) effect on agricultural productivity in different lags positively with 5% confidence. The best lag length is opted using Akaike information, Schwarz and Hannan-Quinn criterion. The results show that 1 percent increase in R&D spending in agriculture, education expenditure in agriculture, government investing in agriculture and rainfall will promote agriculture TFP 0.13 percent by 5 lags, 0.10 percent by 2 lags, 0.14 percent by 1 lag and 0.17 percent at the same time respectively. R&D spending in other sectors (except agriculture) and import of capital inputs in agriculture are contained in the model as research spill-over. The elasticity of these two factors is estimated 0.09 by 5 lags and 0.04 by 2 lags.

KEY WORDS: Agricultural Research and Development in Iran, Agricultural Total Factor Productivity, spill-over.

INTRODUCTION

Productivity growth is an important consideration in agriculture. One way to stimulate the productivity growth rate is to increase the rate of spending in agricultural R&D.

Recently a large body of research has considered the importance of research and development (R&D) in influencing output growth and total factor productivity. Most of these literatures provide theoretical and empirical models that cumulative R&D spending is the main engine of technological progress and productivity growth (see Aghion and Howitt, 1998, Grossman and Helpman, 1991 and Romer, 1990).

R&D investments are still central to agricultural productivity growth. Alston et al. (1999) in the introduction of their recent book on the theme underline that "Throughout the twentieth century improvements in agricultural productivity have been closely linked to investments in agricultural
R&D and to policies that affect agricultural R&D".

Pardy, P. G., et al. (2012) showed countries with larger (smaller) agricultural economies are likely to invest more (less) in agricultural R&D simply because of a congruence effect (Pardey, Kang and Elliott 1989) and concluded that the intensity at which the Asia & Pacific region invests in agricultural R&D has grown much more modestly from 0.43 percent of agGDP (agriculture share of GDP) in 1960 to 0.52 in 2009. While this region has sustained growth in agricultural R&D spending at a comparatively rapid pace, averaging 5.1 percent per year since 1960, agricultural output has grown at reasonably rapid rate as well (3.71 percent per year). Thus the growth in spending on agricultural R&D has more than kept pace with the growth in the value of output, such that the region's research intensity has inched up over time and increasingly so after the mid-1990s.

Given the importance of agricultural R&D to the growth of the sector, many works have been devoted to reporting measures of the returns to domestic agricultural R&D (see recently Esposti (2000) and for a survey Alston et al. (2000). But in a world where the international trade of agricultural products and the dissemination of knowledge are widespread, domestic agricultural productivity depends not only on domestic R&D but also on foreign R&D efforts. This point has been fully recognised, among others, by Hayami and Ruttan (1985) where they emphasise that a country can acquire substantial gains in agricultural productivity by borrowing advanced technology which exists in other countries.

Empirical evidence has been provided by Coe and Helpman's (1995) seminal contribution where they find that accumulated spending on R&D by a country and by its trade partners helps to explain the growth of total factor productivity.

Coe (2008) considered that the importance of international R&D spillovers has long been recognized, although estimates of their empirical significance at the macroeconomic level were often elusive. The search for R&D spillovers across countries received a boost in the 1990s with the development of new growth models by Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992), and by the application of the ideas from these models together with new empirical techniques to expanded data sets by Coe and Helpman (1995) and Coe, Helpman, and Hoffmaister (1997).

Gutierrez and Gutierrez, (2005) analyses, within the new growth theory framework and using panel co-integration techniques, the effect of agricultural international technological spillovers on total factor productivity growth for a sample of 47 countries during the period 1970-1992. They concluded that the United States R&D capital stock has the strongest effect on total factor productivity of its trade partners. A 1 per cent increase in the R&D capital stock in this country increases total factor productivity by an average of 0.087 per cent for the full sample of 47 countries. The effect is stronger for the subset of countries located in temperate zones, where the elasticity rises to 0.123, whereas tropical countries are less influenced by R&D

in the United States. European countries are well integrated. A 1 per cent increase in the R&D capital stock in France increases total factor productivity in Italy by 0.09 per cent, in the Netherlands by 0.14 per cent, in UK by 0.08 per cent. Japan and the USA are less influenced, with elasticities respectively of 0.003 and 0.005 per cent. Similar effects are easily verifiable for an increase in R&D capital stock in Italy, in the Netherlands and in UK.

Khaksar and Karbasi (2005) have computed agricultural TFP of Iran during 1978-2002 using turn-quist Index and considered the impact of agricultural R&D spending on it using Almon Distributing Lag. They concluded that if agriculture R&D spending increases 1 percent, agriculture TFP will increase 0.28 percent by 5 lags in long-run and the impact will remain to 3 years.

Bagherzadeh and Komeijani (2010) considered the impact of agriculture R&D spending on agricultural TFP of Iran during 1979-2009 using Almon Distributing Lag and concluded that the long-run elasticity of this factor is 0.17 percent and rate of return of investing in agricultural R&D spending is 0.36 percent that is much lower comparing the world mean rate (0.51) .

Mehrabi and Javdan (2011) have investigated the relationship between agricultural R&D expenditure and agricultural TFP for Iran during 1974-2007 using Auto Regression Distributing lag model. They computed agricultural TFP using Kendrick’s Index for selected data and concluded that R&D spending has positive significant effect on TFP in both long-run and short run in agriculture sector. That is 1 percent increase in agricultural R&D spending will increase agricultural TFP 0.1 percent. They suggest R&D spending is one of the main factors to improve agriculture growth.

Agricultural R&D spending in Iran

Agricultural research and extension organization in Iran were inaugurated in 1930. The organization began to investigate weather conditions, reallocation of cultivated crops, introducing new production methods and new efficiency factors and promoting new agricultural technologies. The government determined financial expenditure annually. As Table 1 shows, expenditure for agricultural research (as a quota of total research expenditures) increased from 26% to 50% during the period. Spending on agricultural education was mostly at college level and increased over the period. Total agricultural research expenditure had negligible growth (1 per cent per year) from 1980 to 1987 because of the circumstances induced by war.

Table1. Annual averages of Total Research Expenditure, Agricultural Research Expenditure and agricultural education Expenditure in Iran in 1971- 2010 (million Rials)

Year	Research expenditures	Agricultural research expenditures	Agricultural education expenditures
1971-1980	8797.26	2366.82	7385.64
1981-1990	34097.64	13525.26	12944.39
1991-2000	505272.5	255254.7	110335.8
2001-2011	2748634.7	1385762.74	792654.3

Iran Annual budget

Methodology

This section presents a theoretical model that links TFP to the spending on R&D in agricultural sector as Gutierrez et.al (2005) are considered. Assume that agricultural output is produced in a competitive environment and has a Cobb-Douglas production form that contains two important factors; Labor and Capital; and also non durable intermediate inputs.

$Y = AK^{\alpha}L^{\beta}\sum_{j=i}^{N}[(X_j)^{1-\alpha-\beta}]$, α, β>0 , α+β<1 (1)

Where Y is agricultural output, A is a constant, K is capital and L is the amount of labor used to product the final agricultural output. Output is a function of the X_j non durable intermediate inputs, numbered from 1 to N, used in the production process. From equation1, we note first that the production function shows diminishing marginal productivity for each input K,L and X_j and constant returns to scale in all inputs together. Second, the marginal productivity of intermediate input j is dependent of the quantity employed of intermediate input j. thus the innovation of new types of intermediate inputs do not tend to make any existing types obsolete. The technological progress can be seen as improvements in the number N of intermediate inputs and we assume that this advance requires purposive effort in the form of R&D.

Defining the price of intermediate input as p_j and setting output price $p_y=1$, from profit function maximization we can derive the demand for input j.

$$x_j = [(1-\alpha-\beta)AK^{\alpha}L^{\beta} \;/\; P_j]^{\frac{1}{\alpha+\beta}}$$
(2)

In these models, the inventor of new intermediate goods is usually seen as a monopolist who retains a monopoly right over the production and sale of the good that uses his/her design. Assuming a marginal unit cost to produce the intermediate goods, a monopolist will set the price maximizing the following expression.

Max $(P_j-1)X_j$
(3)

Substitiuting (2) in (3), the solution for monopoly price is

$P_j = P = [1/(1-\alpha-\beta)]>1$
(4)

We can now introduce (4) in (2) and utilizing the result in (1) we end with the following production function

$$Y = FK^{a}L^{b}$$
(5)

Where a=α/(α+β), b=β/(α+β) and by definition (α+β)=1, i.e. the production function shows constant returns to scale on the two inputs K and L. the variable F, usually defined as total factor productivity, can be written as

$$F = A^{\frac{1}{\alpha+\beta}}(1-\alpha-\beta)^{\frac{2(1-\alpha-\beta)}{\alpha+\beta}}N$$
(6)

Given α and β as well as A values, it is clear from the above expression that in this model total factor productivity depends on the available assortment of intermediate inputs N: the more intermediates are used in production, the higher is total factor productivity. If the flow of these intermediate goods is proportional to real spending on research and development Re, we have that

$$N(T) = \delta\int_{-\infty}^{T} Re(t)dt$$
(7)

Where δ is a parameter that links, in each period, the growth rate of the number of intermediate inputs to the R&D spending. We therefore have a relationship between current total productivity and cumulative R&D investment. This is central to the innovation based endogenous model and our empirical specification.

Until now innovation has been associated with an expansion in the range of intermediate products used in the production process. We can think of this activity as basic innovation which means new kinds of goods or method of production. Aghion and Howitt (1992) and Grossman and Helpman (1991) also introduce innovation as improvements in the quality of intermediate inputs.

If we assume that in each period the improvements in the quality of products are proportional to real spending in R&D, then a link between total factor productivity and cumulative R&D expenditure can be found once more (Gutierrez, et.al, 2005)

Agricultural Total Factor Productivity

Kendrick Index

Kendrick's index of total factor productivity for the case of value added as output, and two inputs can be written as:

$$TFP = \frac{VA}{\alpha L+\beta K+\delta E} \quad (8)$$

Where TFP, VA, L, K and E stand for total factor productivity, value added, labor, capital stock and energy use in agriculture sector respectively. α, β and δ denote the elasticity of labor, capital stock and energy use with respect to value added respectively in the base year. One way to determine the input elasticities for calculating the TFP, is to estimate the production function in form of Cobb-Douglas and constant returns to scale as a default. Naturally we have that when $\alpha+\beta+\delta 1$ the production function shows constant returns to scale and constancy of factor elasticities over time. The assumption of constant returns has recently received empirical support from Mundlak *et al.* (1997).

Parametric approach consists in econometric estimation of production functions to infer contributions of different factors and of an autonomous increase in production over time, independent of inputs. This later increase which is a shift over time in the production function can be more properly identified as technological progress. It is one of the factors underlying productivity growth. Cobb-Douglas Specification is applied for agriculture production function:

$$VA=AL^{\alpha}K^{\beta}E^{\delta} \quad (9)$$

Where, VA, L, K and E refer to value added, labor, capital stock and energy use in agriculture sector. α, β and δ give factor shares respectively for labor, capital stock and energy use in agriculture. A describes initial conditions. Log-linear form this function can be written as:

$$lnVA = lnA + \alpha lnL + \beta lnK + \delta lnE \quad (10)$$

where lnVA, lnL, lnK and lnE present logarithm of value added, labor, capital stock and energy use in agriculture.

Finally, agriculture TFP function is estimated using OLS method. 6 explaining factors are contained in the model to be estimated how much they can affect agriculture TFP in selected period of time. The model is written as:

$$ln(TFP)_t = f\{ln(Re)_t, ln(Ed)_t, ln(OR)_t, ln(Imca)_t, ln(Ra)_t, ln(Aginv)_t\} \quad (11)$$

Equation1 represents the total factor productivity function in the agricultural sector that has been computed by the Kendrick's index for the selected time period and contains three factors; capital stock, labor and energy use. In this equation, lnTFP, lnRE, lnEd, lnRa, and lnAginv present respectively logarithm of agriculture total factor productivity, agricultural research and development spending, agricultural education expenditure, rainfall and government investing in agriculture sector (which is completely different by research spending) respectively. Two other factors are also contained in the model to show research spill-over effects on agriculture sector; lnOR and lnImca that represent logarithm of research and development expenditure in other sectors (except agriculture) and import of agricultural inputs respectively. The following other studies have also investigated the effects of these variables on agricultural TFP Ali. S(2004), Huffman. W. E and Evenson. R. E

(2001), Kiani. A. K, Iqbak. M and Javad. T (2008), . Rosegrant, M. W. and Evenson, R. E. (1995).

Data

All the variables used in this study were collected as time series data for 1971 to 2011. Agricultural TFP was calculated using the Kendrick's Index that contains agricultural value added and three important factors; agricultural capital stock, labor and energy use. Data for agricultural value added is collected from the Statistics Center of Iran. Data for agricultural capital stock and labor is obtained from Central Bank of Iran for selected time period. Data for energy use in agriculture is obtained from Energy balance sheet of Iran. Data for research and development expenditure in agriculture and other sectors, and also spending on agricultural education are collected from annual budget books of Iran. Government investment in agriculture and import of capital inputs in agriculture sector data is collected from Statistics Center of Iran. Rainfall data is collected from aerology website.

RESULTS

First step of using data for variables in the model is to test the stationary because we have used time series data for all variables. Augment Dicky-Fuler test (ADF), Philips-Peron test (P-P) and KPSS test are applied for the variables and the results are shown in table3.

Table3. Testing stationary using ADF, P-P and KPSS tests.

Logarithm of Variable	Abbreviated name	ADF test	P-P test	KPSS test	Integration degree
Agricultural capital stock	lnK	-6.09	-6.13	0.08	I(1)
Agricultural labor	lnL	-3.58	-6.07	0.13	I(1)
Energy use in agriculture	lnE	-4.68	-4.81	0.18	I(1)
Agriculture value added	lnVA	-8.05	-12.94	0.3	I(1)
Agricultural total factor productivity	lnTFP	-2.37	-6.08	0.09	I(1)
Research and development spending in Agriculture	lnRe	-5.26	-6.27	0.09	I(1)
Education spending in agriculture	lnEd	-7.65	-7.59	0.1	I(1)
Research and development spending in other sectors	lnORe	-7.89	-7.89	0.19	I(1)
Import of capital goods in Agriculture	lnImca	-4.24	-4.05	0.06	I(0)
Government investiment in agriculture sector	lnAginv	-7.52	-7.57	0.06	I(1)
Raining	lnRa	-6.39	-6.48	0.07	I(0)

Source: Calculated by the author

As results in table 3 shows, logarithm of import of capital goods in Agriculture and rainfall are stationary at level and logarithm of Agricultural capital stock, Agricultural labor, energy use in agriculture, Agricultural total factor productivity, Research and development spending in Agriculture, Education spending in agriculture and Research and development spending in other sectors are stationary by first difference.

As Engle-Granger and Sargan and Bhargava (1983) indicate, OLS can be used for variables that are not in the same level of stationary, if the residuals are stationary and the variables have long run relationship. So we have to analysis Engle-Granger test and co-integration regression Durbin-Watson tests on the residuals of the models that will be regressed in last section (Noferesti, 1995).

Agriculture Total Factor Productivity

For computing agricultural TFP, production function must be estimated as presented in previous section. A Cobb-Doglaus function including agriculture capital stock, labor and energy use in agriculture is estimated considering constant return to scale in this part. The results are shown in table 4. The coefficients present the production elasticity of each factor.

Table4.Agriculture Cobb-Daglaus production function estimation.

Parameters	Constant	lnL	lnK	lnE
Coefficient	-3.67	0.67	0.17	0.15
Std-Error	1.14	0.08	0.04	0.07
t-Statistic	-3.19	7.92	4.00	2.10

R^2: 0.98 h-Durbin-Watson:1.96

Source: Calculated by the author

As results in table 4 shows, all coefficients are positive and significant in 5% confidence. Agricultural labor is the most effective in estimated production function. As the production elasticity of labor, capital stock and energy use in agriculture is 0.67, 0.17 and 0.15 percent respectively. Sum of these elasticities equals 1 and they can be used as factor share of value added for computing Kendrick total factor productivity index.

Agricultural Total Factor Productivity is calculated for 1971 to 2011 using Kendrick's Index. The results are shown in table 5.

Table5. Agriculture Total Factor Productivity in Iran (Kendrick's Index).

Year	TFP	Year	TFP	year	TFP	Year	TFP	Year	TFP	Year	TFP
1971	1.88	1978	2.24	1985	2.07	1992	2.76	1999	3.48	2006	3.66
1972	1.95	1979	2.19	1986	2.09	1993	3.10	2000	3.56	2007	3.80
1973	2.05	1980	2.28	1987	1.97	1994	3.23	2001	3.44	2008	3.58
1974	2.14	1981	2.26	1988	2.12	1995	3.57	2002	3.71	2009	3.68
1975	2.28	1982	2.26	1989	2.03	1996	3.69	2003	3.76	2010	3.76
1976	2.36	1983	2.21	1990	2.38	1997	3.63	2004	3.52	2011	3.86
1977	2.36	1984	2.21	1991	2.48	1998	3.84	2005	3.62	2012	-

Source: Calculated by the author

In the last part, equation 11 is estimated to determine the effective factors that effect on agriculture TFP. OLS method is applied to estimating the model using E-Views 7.0. The results are shown in table 6.

Table6. Estimated coefficients of rural poverty index of Iran

Regsessor	Coefficient	Standard Error	t-statistic
Constant	1.97	0.22	8.95
lnRe(-5)	0.13	0.03	4.09
lnEd(-2)	0.10	0.04	2.60
lnORe(-5)	0.09	0.04	2.14
lnImca(-2)	0.04	0.02	2.49
lnRa	0.17	0.06	2.77
lnAgInv(-1)	0.14	0.04	3.77

R-squared :0.95 Durbin-Watson :1.71

Source: Calculated by the author

As table 6 shows, all explaining variables in the model, effect on agricultural productivity in different lags positively with 5% confidence. The optimum lag is determined using Akaike information, Schwarz and Hannan-Quinn criterion. All the variables used in the model are in logarithm form, so the coefficients are presented as the elasticity of each factor on dependant variable.

According to table 6, rainfall is the most effective factor in agricultural TFP, that is, 1 percent increase in rainfall (millimeter per year) will increase agriculture TFP 0.17 percent. Bagherzadeh, A. and Komeijani, A. (2010) obtained a 0.18 percent elasticity of rainfall in agriculturae TFP model in Iran. It is obvious enhancement in raining prepares better condition for cropping. In a country like Iran that is facing droughts some years a major problem is irrigating agricultural lands and rainfall plays an important role in production process. Storing water in dams is suggested to such countries to provide a favorable condition for agriculture.

1 percent increase in agricultural R&D, will enhance agricultural TFP 0.13 percent by 5 lags. As Alston, J. M. and Pardey, G. P. (2007) are considered, best lag period for R&D spending is 2 to 7. Khaksar Astaneh, H. and Karbasi, A. (2005) and Thirtle, C. , Lin, L. and Piesse, J. (2003) obtained the best lag of R&D efficiency is 5 lags. Bagherzadeh, A. and Komeijani, A. (2010) concluded agricultural R&D spending affects TFP by 6 lags in Iran. Research and development spending does not effect on agricultural growth and TFP immediately, but R&D outputs must be learnt, accepted and applied by farmers.

A large amount of new technologies used in agriculture, are borrowed from developed countries that are trade partners. While we have contained these foreign technologies in the model as spill-over; import of capital inputs in agriculture. Spending on Import of such capital goods is borrowing and using knowledge and more efficiency factors in production process. That is, 1 percent increasing in import of capital inputs in agriculture sector will improve agricultural TFP 0.04 percent by 2 lags in Iran. Importing modern agricultural machines has a large share of this factor and usually is accepted by farmers after 1 year to be used for next cropping year.

Another spill-over factor that is contained in the model is R&D spending in other sectors (except agriculture). Because of the relationship between agriculture sector with other economic sectors; Industry, Services and Oil sector, any improvement in these sector may affect agricultural input productivity. As result show, 1 percent increase in R&D spending in other economic sectors will increase agricultural TFP 0.09 percent by 5 lags. R&D spending in agriculture is more effective than other sectors on agricultural input productivity.

Education spending in agriculture is one of the most important factors that cause improvement in agriculture and input productivity. New technologies are often not accepting by rural farmers immediately. Teaching, training and extending the usages of modern findings and research outputs plays the impotent role in applying the new technology in rural agriculture. As results show, 1 percent increase in education expenditure in agriculture will increase agricultural TFP 0.10 percent after 2 years. Research outputs are not usable without training and extending to the farmers and 2 lags show the acceleration applying new technologies by training farmers.

Last factor that is contained in the model is government investment in agriculture and is presented positive effectively. Agricultural TFP will increase 0.14 percent, if government increases investing in agriculture 1 percent after 1 year. Mehrabi,B. H. and Javdan, E. (2011) shows a 0.17 percent elasticity for this factor in TFP model in long-run in agriculture sector in Iran.

Totally, we have tested the stationary of residual of the estimated model. The results are shown in table 7.

Table7. Engel-Granger and CRDW test.

Dependent Variable	Engle-Granger test	CRDW
LTFP	-4.23**	2.84*

The null hypothesis has a unit root at 1% (**) and 5% (*).

Source: Calculated by the author

According to table7, residual time series of the previous estimated model is stationary in level and as Engle-Granger and Sargan and Bhargava (1983) indicate, the results are reliable .

CONCLUSIONS

This paper addresses how much do agriculture R&D and R&D spill-over affect total factor productivity in the agricultural sector In Iran. Although this is not a new question, only recently has the new economic growth literature provided theoretical as well as empirical models to analyse this field of research.

This paper answers to this problem by computing total factor productivity in the agricultural sector during the period 1971-2011 using Kendrick’s Index and uses this variable to analyse its relationship with domestic and foreign public R&D spending in agriculture. Results show agriculture total factor productivity is positively and significantly influenced not only by its domestic R&D capital stock but also by the foreign R&D capital stock of its trade partners.

6 factors are contained in the agriculture TFP model; agriculture R&D spending, agriculture education expenditure, government investing in agriculture and rainfall; and two factors as spill-over; R&D spending in other sectors and import of capital inputs in agriculture.

Augment Dicky-Fuler, Philips-Peron and KPSS test is applied for all variables used in the model to test their stationary. Logarithm of import of capital inputs in agriculture and rainfall time series data are stationary in level and all other variables are stationary by first difference.

We estimated agriculture TFP model using OLS model by E-Views 7.0 and the results are shown in table 6. All explain variables show positive significantly effect on TFP by different lags. 1 percent increase in R&D spending in agriculture, education expenditure in agriculture, R&D spending in other sectors, import of capital inputs in agriculture, government investing in agriculture and rainfall will increase agriculture TFP respectively 0.13 percent by 5 lags, 0.10 percent by 2 lags, 0.09 percent by 5 lags, 0.04 percent by 2 lags, 0.14 percent by 1 lags and 0.17 percent at the same time.

R&D spending in agriculture is more effective than R&D spending in other sectors. Rainfall is the most effective and import of capital inputs in agriculture is the least effective factor in agriculture TFP model.

REFRENCES

1. *Aghion, P., and P. Howitt, 1992, "A Model of Growth Through Creative Destruction," Econometrica, 60, pp. 323–51.*
2. *Aghion, P., and Howitt, P. (1998). Endogenous Growth Theory. Cambridge MA, MIT Press.*
3. *Ali. S (2004), Total Factor Productivity Growth in Pakistan's Agriculture: 1960-96, Pakistan Development Review. 43(4): 493-513.*
4. *Alston, J.M., P.G. Pardey, and V.H. Smith eds (1999), Paying for Agricultural Productivity, Baltimore, Johns Hopkins University Press.*
5. *Alston, J.M., Chan-Kang, C., Marra, M., Pardey, P.G., and Wyatt, T. (2000). A Meta-Analysis of Rates of Return to Agricultural R&D. Washington D.C.: International Food Policy Research Institute.*
6. *Alston, J. M. and Pardy, G.P. (2007). Attribution and other problems in assessing the returns to agricultural R&D. Agricultural Economics, 25: 212-254*
7. *Bagherzadeh, A. and Komeijani, A., 2010, Measurement and Analysis of investment rate of return on agricultural research of Iran, agricultural Economy, no.2.*
8. *Coe, D.T. and Helpman, E. (1995). International R&D Spillovers. European Economic Review, 39: 859-887.*
9. *Coe, D., and E. Helpman and A. Hoffmaister, 1997, "North-South R&D Spillovers," Economic Journal, 107 (January), pp. 134–149.*
10. *Coe, D. T., Helpman, E. and Hoffmaister,A. W., 2012, International R&D Spillovers and Institutions, IMF Working Paper Asia and Pacific and European Departments, 2008 International Monetary Fund.*
11. *Engele, R.F. and C.W.J Granger, 1987. Co-integration and Error Correction: Representation, Estimation and Testing, Econometrica Journal, 55: 251-276.*
12. *Esposti, R. (2000). Public R&D and Extension Expenditure on Italian Agriculture: an Application of a Mixed Parametric-Nonparametric Approach. European Review of Agricultural Economics, 27(3): 365-384.*
13. *Grossman, G. and Helpman, E. (1991). Innovation and Growth in the Global Economy. Cambridge, MA: MIT Press.*
14. *Gutierrez, L., and Gutierrez, M. M., 2005, International R&D Spillovers and Productivity Growth in the Agricultural Sector, A Panel Cointegration Approach, Department ofAgricultural EconomicsUniversity of Sassari, Italy*
15. *Hayami, Y. and Ruttan, V. W. (1985). Agricultural Development, an International Perspective. Baltimore: The John Hopkins University Press.*
16. *Huffman. W. E and Evenson. R. E (2001), Structural and Productivity Change in US Agriculture: 1950–1982, Agricultural Economics, 24(2):127–47.*
17. *Khaksar,A. H. and Karbasi, A., 2005, calculating investment marginal rate of return on research in agriculture of*

Iran, Agricultural Economy and Develpement, no. 50.

18. *Kiani. A. K, Iqbak. M and Javad. T (2008), Total Factor Productivity and Agricultural Research Relationship: Evidence from Crops Sub-Sector of Pakistan's Punjab, European Journal of Scientific Research, 23 (21), 87-97.*
19. *Mehrabi,B. H. and Javdan, E., 2011, Impact of research and development on growth and productivity in agriculture sector of Iran, Journal of Agricultural Economics and Development Vol. 25, No. 2, Summer 2011, P. 172-180*
20. *Mundlak, Y., Larson, D. and Butzer, R. (1997). The Determinants of Agricultural Production Function : a Cross-Countries Analysis. World Bank Working Paper, 1827. Washington, DC: World Bank.*
21. *Noferesti, M., 1995. Unit Root and Co-integration in Price of Rural Area. Econometrics.*
22. *Pardey, P.G., M.S. Kang, and H. Elliott. "The Structure of Public Support for National Agricultural Research Systems: A Political Economy Perspective." Agricultural Economics 3(4)(December 1989): 261-278.*
23. *Philip G. Pardey, Julian M. Alston, and Connie Chan Kang, 2012, Agricultural Production, Productivity and R&D over the Past Half Century: An Emerging New World Order, International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August, 2012.*
24. *Romer, P. (1990). Endogenous Technical Change. Journal of Political Economy, 98: 71-102.*
25. *Mark W. Rosegrant and Robert E. Evenson, 1995, Total Factor Productivity and Sources of Long-Term Growth in Indian Agriculture, International Food Policy Research Institute 1200 Seventeenth Street, N.W.Washington, D.C. 20036-3006 U.S.A.*
26. *Sargan, J.D. and A. Bhargava, 1983. Testing Residual from Least Square Regression for Being Generated by the Gaussian Random Walk. Econometrica Journal, 51: 153-174.*
27. *Thirtle1, C., Lin, L. and Piesse, J., 2003, The Impact of Research Led Agricultural Productivity Growth on Poverty Rrduction in Africa, Asia and Latin America, 25th International Conference of Agricultural Economists (IAAE), ISBN Number: 0-958-46098-1*