AN EXAMINATION OF AGRICULTURAL PRODUCTIVITY AND RETURNS TO AGRICULTURAL RESEARCH IN TURKEY

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Table of Contents

List of Figures

List of Tables

Executive Summary

The Turkish economy is dependent upon the agriculture sector as a source of employment and economic growth. Agriculture makes up about 15% to 16% of the Turkish GDP and more than one-third of the population as such is very important. The productivity growth of the sector is extremely important if the government wishes to have food prices not increase for a population that is growing at approximately 1.7% per annum.

This paper reviews the current economic methods for estimating agricultural productivity. We then proceed to estimate the growth in Total Factor Productivity (TFP) for the period 1967-97. TFP is the ratio of an output index and an input index. We made a detailed search of input use and output production for Turkish agriculture for the entire period (all data is reported on a disk). Much of this data has not been brought together before for the agriculture sector in Turkey and as such represents a contribution in its own right.

We then estimated the TFP using the Tornqvist index. Our results show that the TFP increased at an annual rate of 4.07% over the entire period. However when we examine the period 1967-88 the growth was 5.58% and for the period 1988-96 the growth rate was -0.06%. This lower growth rate suggests that the productivity growth in the sector has stopped; a major concern for the Turkish government. We also found that the TFP index and Research an Development index in Turkish agriculture are cointegrated. The econometric estimation yielded a long-run Research and Development expenditures elasticity TFP around unity.

Estimated Average Growth Rates of Output, Input and TFP in Turkish Agriculture

Year	Output Growth rate	Input Growth Rate	TFP Growth Rate
1967-96	6.16	1.99	4.07
1967-88	8.21	2.51	5.58
1989-96	0.53	0.55	-0.06

Source: Estimated

Within agriculture two of the most important crops are wheat, the staple commodity, and cotton which is the most important industrial crop in the country. Cotton is used by the textile industry which is a large employer of labor in the Turkish economy. As Turkish government has a strategic interest in yield increasing research in both of these crops they were chosen as two examples of where we could calculate the rate of return to agricultural research, something that has not been done for any part of the Turkish agricultural sector.

Estimated returns for wheat and cotton research in Turkey and Pakistan

Commodity	Assumptions	Country	Authors	IRR
Wheat	Yield increase of 1%, budget 5%	Turkey	Ours	67%
Wheat	Yield increase of .5%, budget 5%	Turkey	Ours	56%
Wheat	Yield increase of .5%, budget 50%	Turkey	Ours	32%
Wheat		Pakistan	Nagy(1996)	137%
Cotton	Yield increase of 1%, budget .5%	Turkey	Ours	277%
Cotton	Yield increase of .5%, budget .5%	Turkey	Ours	245%
Cotton	Yield increase of .5%, budget 10%	Turkey	Ours	124%
Cotton		Pakistan	Nagy(1996)	101%

Source: Estimated and Nagy (1996)

Our estimated internal rate of return (IRR) for wheat research ranged between 32% and 67% and for cotton 124% and 277%. The IRR is the interest rate that makes the net present value of the investment equal to zero. These rates indicate that the past returns to government investment in agricultural research have been very high in Turkey.

For a comparison Nagy and Quddus found the IRR for wheat research in Pakistan to be 137% and cotton 101% for a similar time period. We conclude that our estimates are a reasonable approximation of the return on investments made in agricultural research in Turkey. Clearly the Turkish government is under investing in agricultural research which puts it in the company of virtually every other country in the world.

1.0 Introduction

Agriculture is very important in most developing countries of the world and Turkey is no exception to this rule. As the country develops and releases labor from agriculture into the other sectors of the economy productivity is expected to increase. Increases in agriculture also has a direct effect on the price of food in Turkey. Two of the important sectors for food and employment are wheat and cotton.

Wheat is a staple food commodity in the Turkish economy. The consumption of wheat is estimated to be over 220kg per capita which is one of the highest if not the highest consumption level in the world. The current level of wheat production is between 16 – 18 Mt. annually on over 4 million Turkish farms. The trade in wheat has been small as Turkey has imported some years while exporting others. The reason for trade is more to do with the lack of high quality wheat and the need to sell surplus low quality wheat than the shortage of wheat volume. As argued by Yildirim et. al. the reason for the lower quality production is due to institutional incentives rather than weather or varieties.

Cotton is important because of the large textile industry in Turkey. The policy of the government has been to expand the textile industry often by taxing exports while at the same time supporting the domestic price. The attempt was to have a large domestic supply of raw cotton for manufacturing while protecting producer incomes. It is not the purpose of this paper to evaluate this policy, however we do point out that as a result of this policy Turkey has treated cotton in a closed economy framework.

The agricultural research community in Turkey, which is described in more detail latter in this report, is specialised into various crops, livestock, vegetables, and other agricultural issues such as soils and management. In this research report we focus only on the wheat research and cotton system.

Wheat yields in Turkey have increased over the years as shown in table 0.1. This increase has been due to increased use of fertilizer, herbicides, management and new varieties. The green revolution has also played and important role in the increase of yield of spring wheat in Turkey, Bayrı(Yıldırım) and Furtan, 1990. However, within Turkey there has been an active wheat-breeding program that has also increased yields(Mızrak, Uzunlu and Düşünceli, 1997).

Research as an investment is not a new idea. Since Griliches paper on hybrid corn there has been numerous papers written attempting to place a value on the returns to agricultural research. This literature has been summarized by Ruttan and more recently be Alston et. al. all of which showed the returns to be high (high as in above the long run market rate of return).

To date no study has been done that examined the returns to agricultural research in Turkey. Turkey has a large and growing population and therefore having an increase in wheat supply is important. Because acreage is now fully used the increase in supply will have to come through yields.

2.0 Overview of the Agriculture Research Organisation in Turkey

Research in agriculture has played an important role in the development of Turkish agriculture. Particular advances have been the transfer of high yielding varieties suitable for various agro-ecologies and dissemination of developed production techniques.

Historically, Turkish agricultural research system has evolved in several distinct lines starting shortly after the establishment of the Turkish Republic. The main goal of research efforts was to reach self - sufficiency in food production. A few research stations were established in 1920s and early 1930s in Central Anatolia to carry out research on veterinary, agronomy, horticulture, and plant protection followed by water and soil research institute in 1960s and many other crop specific research institutes under the umbrella of Ministry of Agriculture and Rural Affairs (MARA). After 1950s, several crop specific research institutes were also established by other ministries. Along with these research institutes, higher education in agriculture was also started in 1930s. These higher education institutions later were developed into agricultural and veterinary faculties (Mızrak et al., 1997).

Agricultural Research (AR) in Turkey is mainly carried out by public institutes. A considerable part of agricultural research is performed by General Directorate of Agricultural Research (GDAR) of MARA. In addition to MARA, General directorates of

Rural Services (GDRS), Universites, State Economic Enterprises (SEE), and some NGOs also conduct agricultural research.

Research Institutes are the most critical component of research and development activities which provide research input relatively more important in agricultural sector compared to other sectors since ecology dependent nature of agricultural technologies seriously limit the transfer of technologhies developed under specific ecological conditions. Economic, social, and cultural factors also dictate regionalized agricultural research for higher relevancy.

There are 51 research institute (RI) under GDAR scattered over nine agricultural regions. These research institutes mainly conduct strategic, applied and adaptive research on various fields. Four of these research institutes are Central Research Institutes (CRI) with responsibilities of field crops, horticultural crops, livestock production, and animal diseases. CRIs have national responsibilities for coordinating and guiding regional research institutes efforts.

GDAR also has eight Regional Research Institutes (RRI) in Aegean, Blacksea, Mediterranean, Cukurova, Central Anatolia, Southeast Anatolia, East Anatolia and Trace regions. These research institutes undertake applied and adaptive research in their mandated regions. Remaining 39 RI’s are crop or livestock specific institutes.

The distribution of RI is highly uneven. About 35 % of the RI are located in the western part of Turkey. Therefore, eastern part of Turkey contains a disproportionately large percentage of disadvantaged farmers, and crop yields are substantially less then that of western part of Turkey.

One of the main onjective of the Turkish gevernment in the agricultural sector is to modernize further and disseminate improved production techniques in order to rise productivity, yields and farmers income. Therefore, the government of Turkey has taken measures to strengten agricultural research.

RI under GDRS are second most important component of research systems in Turkey. GDRS has 12 RI well scatterd aroud the country. The main area of research are hidrology, soil and water conservation, irrigation and drainage, soil fertility, plant nutrition, and mechanization.

Few govermental organizations are involved in AR in Turkey. Atomic Energy and Nuclear Research Assosiation (AENRI) of Turkey is concentrated on utilisaiton of nuclear techniques in plant nutrition and breeding, soil fertility, food storage, and animal health. Some SEEs under different ministries conduct agricultural research on related commodities such as sugar beet, tobacco, tea, and opium. In addition, private seed companies carry out adaptive studies on imported varieties. Private companies support some of the public research activities. Agricultural and Forestry section of Turkish Scientific and Technical Research Organization (TUBİTAK) provides research funds for various projects mainly for the universities.

Total research staff in the Turkish agricultural research systems is 1360, of this 78 % is employed in RI of GDAR. 40 % of this research staff has M.Sc. and Ph.D. In addition, 700 support staff and 4600 permanent and temporary labor is also employed. However, there is a strong imbalance in the regional distribution of staff and employee.

Research Priority Areas (RPA) are determind based on the evaluation, assessment, and review of on-going research activities, research resources, and research requirements of agricultural production systems and development objectives. These RPAs are then ranked on the bases of potential benefit, ability to capture benefit, research capacity and research potential. Individual research program priorities in each RPAs are also determined in a similar manner. Representatives of public, private sector and universities involve in priority setting process. Research Advisory Committees (RAC) assesses Research Project Proposals (RPP) based on relevans, scientific excellence, technology transfer potential, capacity, originality, collaboration, equipment and training needs, and cost effectiveness. All these principles are included in the Research Master Plan (RMP) developed by GDAR and GDRS, and currently financed by the World Bank, with a mission of providing economic, social, and environmental benefit to Turkey through high quality and relevant agricultural research.

RMP guiding principles for the research strategy can be given as focusing support on high priority research opportunity areas, emphasizing on multidisciplinary research projects, targetting industry needs, and maintaining the balance between longer term strategic and shorter term applied research. In addition, under RMP, GDRS plans to develop centers of exellence by strengthening existing capacity and linking them through collaborative research programs to other research providers with complementary skills, encourages the involement of international researchers and research centers, guides research initiatives to minimize doublications, develop a research database, regularly monitor the projects, and foster the transfer of technology (Anonymous, 1995). Some identified high research program priorities include yield and quality improvement of crops and animal production, integrated pest management, disease diagnosis and management of livestock, bees, and aquaculture, water storage, land use, protection of soil and water resources, rangeland improvement, water use efficiencies, and economic issues in agricultural development.

2.1 Research extension linkages

Linkage between research and extension in Turkey was not very strong. Agricultural Extension and Applied Research Project (TYUAP) was initiated with a World Bank loan in 1983 in order to strengthen the research-extension linkage. TYUAP is a system approach mainly to strengthen extension. It is characterized by a) the inclusion of farmers along with research and extension staff in identifying, prioritizing, testing, and evaluating agricultural research on a continuing basis, b) research directed toward the development of technologies that are location specific and meet the needs of farmers, c) cooperation between research and extension to achieve effective farmer use of information, and d) development of human resouces required to sustain the program.

Resrach institutes have a variety of roles in this context: to investigate topics of potential importance to farming community and to provide a source of technical expertise to extension staff; to train Subjec Matter Specialists (SMS); to adapt potentially useful research findings to local requirements and verify their usefulness throgh on-farm resrach trials. Responsibilities of Provincial Directorates (PDs) as the extention instututions within the project are as follows: to develop agricultre in the province, enabling farmers to obtain greatest sustainable return from farming and farm-based activities; to provide linkages with research institutes; to relay to researchers information from Village Group Techicians (VGTs) concerning farmers' reaction to demonstrations, and recommendations; to provide a link between farmers and resarch staff for the solution of farmers problems and for the dessemination of apppropriate research findings. However, TYUAP could not be institutionalized, and research priorities are determined without the involement of farmers and extension agents. In that sence, the linkage between research and extension is weak.

2.2 Wheat Research

Wheat is the most important crop in Turkey, occupying 35 % of cultivated area (about 9.35 million hectares). The relative importance of wheat measured as a percentage of the total cultivated area has increased somewhat steadily since 1920's. Wheat is rarely used as animal feed, and serves as the most important carbohydrate component of the Turkish diet. Marketing ration of wheat was 64 % in 1996. The share of wheat in total value of crop production was 51 % in that year (SIS, 1998).

A smaller proportion of the output growth has been due to increase in the area sown to field crops which was permitted by a rapid expansion in mechanisation prior to 1960s. Research projects launched in the 1960s and extensive use of second generation inputs such as fertiliser and chemicals have contributed to output growth in later decades.

Wheat yield increased by almost 2 % per annum from 1961 to 1974 and 0.8% afterwards, indicating the impact of wheat project in the late 1960s. This was combined with a favorable market price support and input subsidy. There was a huge and continuous expansion in fertilizer use in Turkey between 1960 to 1990. It increase 9.5 million tons in 1990 from 425 tons in 1963. In the recent years, use has fluctuated but has not increased further on average. Pesticide use on the other hand does not appear to have increased in last two - three decades. There has been a rapid mechanisation in Turkish agriculture. Number of tractors rose from 42 thousand to more that 807 thousand between 1960 and 1996 (SIS, 1998).

Wheat research activities can be summarized in two periods: Pre-project period (1926-1969) and project era (1970-1996) (Zencirci et al, 1997). A research project was initiated to increase wheat production in late 1920s, and several cultivars wer released. Meanwhile, some cultivars form Canada, Italy, and Australia were also introduced to Turkey. In addition, agronomic studies were also conducted mainly in Central Anatolia.

After 1966, spring wheat cultivars form International Wheat and Maize Improvement Center (CIMMYT) were imported and widely cultivated in Central Anatolia and transitional zones of Turkey.

Turkish Goverment and Rockefeller Foundation established a dynamic contry-wide wheat improvement project in 1967. The objectives of the project were to 1) establish a milty-disciplinary wheat program, 2) develop a package of growing techniques for newly developed varieties, 3) reduce yield losses, 4) improve soil and water use thereby increase yields, 5) investigate wheat production economics, and 6) provide training for national researchers.

Wheat Research and Training Project, with 10 research station in different ecological zones, conducted a series of agronomic trials, strenghtened breeding and pathology studies. New varieties resistance to rusts and septoria were developed for coastal region, with sufficient duration to permit early sowing in autumn. A series of tillage practices were conducted to promote the early establishement of seeding and conserve maximum amount of moisture in the fallow land in rainfed areas. Developing high yielding cultivars with high yield satbility and resistant to disease and lodging were aimed at in the breeding program for rainfed areas. A total of 28 bread wheat and 10 durum wheat cultivars have been developed since the beginning of the project.

There are two distinct wheat-growing areas: the dry, cold winter wheat area of the Central Plateau and South-East Turkey, and the warmer, wetter spring wheat areas of the coasts. In the winter wheat areas, the major problem in wheat production is the lack of moisture. A set of tillage practices permitting early establishment of the wheat seedlings was developed. A number of varieties adapted to these areas have also been developed accordingly. Most commonly sown winter wheat varieties according to area devoted are Gerek-79, Bezostaya, Kıraç, and Saraybosna and durum wheat varieties are Kunduru, Cakmak-79, Diyarbakir-81, Dicle-74, Sham-1, and Gediz-76.

In the spring wheat areas the most pressing problem is the identification of varieties which have a good resistance to stripe rust, septaria and which are long enough in duration to permit sowing in early October yet which will not flower until April. Most commonly sown spring wheat varieties are Seri-82, Cumhuriyet, and Panda.

2.3 Relations with international research systems

Turkish agricultural research systems have a good connection with some of the international research systems. Turkey and CIMMYT have a long work experience together on wheat research for years. A systematic effort has been carried out since 1969. Turkey signed and agreement with CIMMYT with the aim of improving world cereal production through scientific and technical research in 1980 and 1986. Turkish Government has a strong interest in strenghtening its agricultural reseach and production programs. This could attain positions serving as examples or to assist in the transfer of technology to developing countries of the region. CIMMYT has likewise as its major objectives the conduct of research on maize, wheat, barley, and triticale. In that respect, Turkey and CIMMYT have common objectives to promote and accelerate the progress of research and training in the cultivation of crops mentioned above. Therefore, the two parties established a formal relationship between the scientific and technical divisions of each party.

Both parties provide the program with consultation, assistance, research specialists, seed materials, facilities, supply and equipment etc. In addition, exchange of breeding materials has beed freely cunducted between CIMMYT and Turkey, and the research findings have been published in the public interest as joint or separate publication. Turkey also assure the unrestricted, expeditious movement of seed and genetic stocks into and out of Turkey as may be required to promote the cooperative programs with proper respect to current laws and quarantine procedures.

With the agreement in 1986, a joint winter wheat improvement project was initiated. This project became a tripartite program between Turkey, CIMMYT, and International Center for Agricultural Research in tht Dry Areas (ICARDA). Rainfed agriculture is extremely important tor Turkey, and the Ministry of Agriculture and Rural Affairs is concerned with the increasing the output in rainfed agriculture. ICARDA's major objectives is to carry out research on rainfed agricultural systems, wheat ect.

Turkey and ICARDA signed a Memorandum of Understanding to collaborate on the common objectives in 1986. Both parties have agreed on exchange of scientist, breeding material and germplasm, reseach experience, data, scientific literature, and methodology. ICARDA provides Turkish National Research Systems with consultancies, travel funds, visits to ICARDA, scholarships, seed materials, publications, research equipments, and funds for co-sponsoring research projects, workshops, and in-country training courses. Turkish government provides office, laboratory, and land for research, support staff for cooperative research, supplies and equipments.

These two parties have a various collaborative projects aiming at increasing the produciton of cereals and food legumes, improiving rainfed farming systems, pasture, forage, and livestock production, and developing genetic resources. Benefits from research findings have been used by both parties, and research findings have been published.

2.4 Variety Licensing

Centre for Seed Licensing and Certification (CSLC) under MARA issues the license for developed varieties. Varieties developed within the country and outside the country can be submitted for licensing. CSLC is responsible for carrying out experiments, taking the observations, analysing the experiments, preparing reports about performances of the varieties proposed for licensing, and organising meetings for Licensing Committee (LC). This Committee issues license for developed varieties. CSLC is also in charge of keeping all the documents about the varieties licensed and preserve the samples of the varieties as long as the variety is in production.

Licensing Committee is formed of eight members; one from General Directorate (GD) of Protection and Control (GDPC), one form GD of Agricultural Research (GDAR), one from GD of Agricultural Production and Development (DGAPD), two from the universities, 2 from the public research institutes, and two from CSLC. LC approves the variety based on the performance show in the regional for which it is developed.

Research Institutes are in charge of producing foundation and original seeds varieties they develop. After licensed, original seeds are multiplied by General Directorate of State Farms (GDSF). The foundation goal of GDSF is to meet the needs of agricultural industry in a broader sense. Among others, the main objective of GDSF is to multiply developed seeds, seedlings, and bred animal and to distribute to farmers in order to increase the crop and animal production and rise agricultural income. In addition, GDSF also builds processing plants to produce more value- added products, supports research on breeding, markets the excess production, inform farmers about new varieties and techniques, collaborate with farmers and private sector in seed production etc.

Certified seed distribution of wheat and barley has been declining in the last ten years. Amount of distributed wheat seeds increased to 178 thousand tons in 1987 form 50 thousand tons in 1950. However, amount of distributed seeds decreased to approximately 80 thousand tons in last years. MARA plans to distribute about 300 thousand tons of wheat seed every year but can not meet this demand through the production by GDSF. Therefore, some private companies also produce certified wheat seeds.

Farmers can also obtain limited amount of seeds directly from research institutes. Some Provincial Directorates (PD) multiply certified seeds and distribute to farmers as PDs are the implementing agencies of extension, they have the responsibility to inform and provide farmers with the developments.

3.0 Measuring Productivity and Productivity Growth

Productivity of a sector refers to the ratio of output produced to the inputs used in the production process. Countries that have high levels of productivity are wealthy. Economists are interested in the level of productivity, particularly when compared over time and to other countries. Economists are also concerned with the change, or growth in productivity as it measures whether the sector is becoming more efficient. In this later case we calculate the growth in productivity over time using index numbers.

Productivity is defined to be ratio of outputs to inputs used in the production process, it is therefore an index. Growth in productivity is that part of the growth in output that cannot be explained by the increase in input use, and for this reason

Abramovitz (1956) called it residual output growth. This residual output growth is obtained by subtracting the weighted increase in input quantities from the observed increase in output. The residual output growth may be attributed to various factors, such as technical change, economies of scale, efficiency improvement, increases in capital stock, etc. Recent econometric analysis has been able to sort out these different effects of output growth so that we now can get an accurate estimate of technical change, which is the most commonly cited source of productivity growth.

In the early stages of research into productivity growth, the main work of economists was to develop alternative measures of the “residual output growth”. By the end of the 1970s, several economic measures of productivity growth had been developed by economists. However, since the early 1980s, when economic growth started slowing down, the focus shifted to explaining the changes in productivity. In the attempt to explain the productivity slowdown in many developed countries, considerable effort was directed to develop a framework capable of identifying and measuring the separate contribution of various factors into productivity growth. Thus, decomposition of productivity growth, rather than just its measurement, became the interesting topic in the field.

Since Solow’s (1957) classic paper, considerable effort has been directed at improving the methodology for measuring and explaining productivity growth. To date, there are three alternative approaches for measuring productivity (Capalbo and Antle, 1988): (a) the accounting approach, based on index numbers and primarily concerned with measurement without being able to provide an explanation of productivity changes; (b) the parametric approach with strong theoretical foundation based on econometric techniques to measure and to decompose the growth rate of productivity; and (c) the non-parametric approach, that relies on mathematical programming concepts. The different methods used to evaluate productivity are shown in figure 1.0, and a detailed review of these approaches is presented in the following sections.

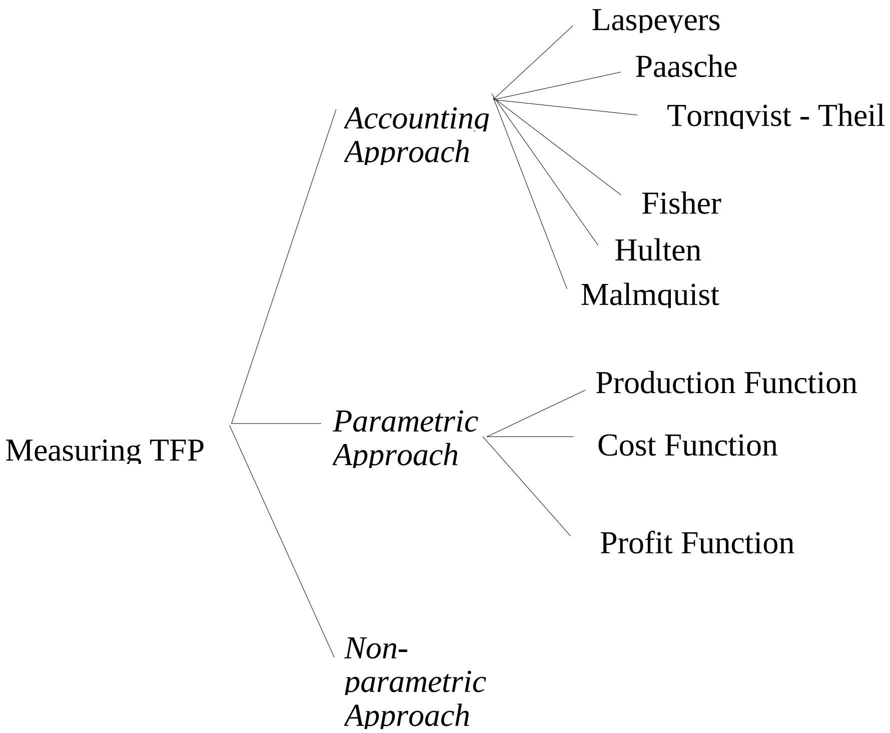

Figure 1.0 Alternative Approaches to Measure TFP.

3.1 Partial *vis-à-vis* Total Factor Productivity Measures

Productivity growth can be measured by two alternative ways: partial and total factor productivity (TFP) measures. Partial productivity measures are defined upon a specific factor input and they show how much output has increased over time by holding the quantity of the particular input constant. In a sense they are similar to average physical product. On the other hand, total factor productivity measures are defined upon all inputs used in the production process, in terms of an aggregate input quantity. There are several ways to aggregate input quantities, with the difference being in the weights used in each case.

There are serious concerns about the accuracy of partial factor productivity measures in terms of their unbiasedness in accounting for productivity growth. Jensen (1957) provided some intuitive examples for such biases. For illustration purposes consider one of them, where there are two sectors in the economy. In terms of labour productivity the first sector has achieved higher rates of growth than the second one. In terms of capital productivity, however, the opposite may be true, if technical change in the first sector is Harrod-neutral and in the second is Hicks-neutral. Thus, by using the partial factor productivity measures, economic performance among sectors cannot be ranked uniquely.

There are however, two special cases where partial and total factor productivity measures provide precisely the same information about economic performance. First, when production technology is characterised by fixed proportions (i.e., a Leontief production function), similar trends in productivity growth are obtained no matter which input is used to calculate partial factor productivity. Second, trends in partial factor productivity are a good approximation of trends in total factor productivity as long as partial factor productivity is measured with respect to relatively more scarce factor (Hayami and Ruttan, 1985).

3.2 The Accounting Approach

The accounting approach, which was the first method for measuring TFP, is based on index numbers. Its main advantage is that it can be used regardless of many inputs and outputs are included in the analysis. On the other hand, its main disadvantage is that it can only provide a measure of TFP without being able to identify its sources of growth. There have been six different indices used to measure TFP. These are presented in table 1.0. Each one provides a different way of weighting output and input growth and also relies on different assumptions concerning the functional form of the underlying production function. Therefore, measures of TFP based on various index numbers will be different in magnitude.

Laspeyers and Paasche TFP indices are compatible with a linear or a Leontief production function. In the former, factor inputs are perfect substitutes for each other while in the latter input quantities are used in fixed proportion. Given that the Laspeyers and Paasche TFP indices are exact for only these two production function forms (Diewert, 1976), their usefulness in applied analysis is limited. Moreover, the use of Laspeyers index in measuring TFP introduces a negative bias; that is, TFP is underestimated. The opposite occurs when Paasche indices are used to aggregate inputs and outputs. If, however, the assumption of perfect competition in both input and output markets is fulfilled along with constant returns to scale and Hicks neutral technical change, then TFP measures based on Laspeyers and Paasche indices consist the upper and the lower limits, respectively (Ruttan, 1957). Thus, these two measures of TFP may only be used to provide an optimistic and a pessimistic measure of TFP.

The Divisia index and in particular its discrete approximation developed by Tornqvist and Theil is the most popular tool within the accounting approach. In this case, inputs and outputs are aggregated with revenue and cost shares as weights. Following Diewert (1976), the Tornqvist-Theil TFP index is exact for a linearly homogeneous translog transformation function, satisfying strong separability between inputs and outputs and Hicks neutral technical change. Moreover, given that translog is a flexible function form, this index is superlative. The Tornqvist-Theil index has been used to measure TFP in the agricultural sector of USA (Ball, 1985); Ireland (Glass and McKillop, 1989); UK (Thirtle and Bottomley, 1993); Zimbabwe (Atkins and Thirtle, 1995); Spain (Fernadez, Herruzo and Evenson, 1995); Japan (Kuroda, 1995); Greece (Mergos and Karagiannis, 1997); and Canada (Fantino and Veeman, 1997).

In recent years there is a growing interest among agricultural economists in the Fisher TFP index. In this formulation, aggregate quantities are defined to be the geometric mean of Paasche quantity indices and aggregate prices to be the geometric mean of Laspeyers price indices. Also it is required that producers maximise profit, operating in a perfectly competitive market (Diewert, 1992). Caves, Christensen and Diewert (1982) show that the Fisher TFP index is exact for a second-order quadratic transformation function, which is strongly separable between outputs and inputs, allows for Hicks neutral technical change and it is characterised by non-increasing returns to scale. In addition, Fisher index is superlative, as the second-order quadratic transformation function is flexible. Bureau, Fare and Grosskopf (1995); Ball, Bureau, Nehring and Sowwaru (1997); and Fantino and Veeman (1997) used the Fisher index to measure TFP in the agricultural sector of the EU countries, the US and Canada.

Table 1.0: Total Factor Productivity Indices

Laspeyers	$\dfrac{\sum_{j=1}^{n} p_{jt}Q_{jt}}{\sum_{j=1}^{n} p_{jt}Q_{jt-1}} \bigg/ \dfrac{\sum_{i=1}^{m} w_{it}X_{it}}{\sum_{i=1}^{m} w_{it}X_{it-1}}$
Paasche	$\dfrac{\sum_{j=1}^{n} p_{jt-1}Q_{jt}}{\sum_{j=1}^{n} p_{jt-1}Q_{jt-1}} \bigg/ \dfrac{\sum_{i=1}^{m} w_{it-1}X_{it}}{\sum_{i=1}^{m} w_{it-1}X_{it-1}}$
Tornqvist-Theil	$\dfrac{\sum_{j=1}^{n} R_{jt}Q_{jt}}{\sum_{j=1}^{n} R_{jt-1}Q_{jt-1}} \bigg/ \dfrac{\sum_{i=1}^{m} S_{it}X_{it}}{\sum_{i=1}^{m} S_{it-1}X_{it-1}}$
Fisher	$\left[\left(\dfrac{\sum_{j=1}^{n} p_{jt-1}Q_{jt}}{\sum_{j=1}^{n} p_{jt-1}Q_{jt-1}}\right)\left(\dfrac{\sum_{j=1}^{n} p_{jt}Q_{jt}}{\sum_{j=1}^{n} p_{jt}Q_{jt-1}}\right)\right]^{1/2} \bigg/ \left[\left(\dfrac{\sum_{i=1}^{m} w_{it-1}X_{it}}{\sum_{i=1}^{m} w_{it-1}X_{it-1}}\right)\left(\dfrac{\sum_{i=1}^{m} w_{it}X_{it}}{\sum_{i=1}^{m} w_{it}X_{it-1}}\right)\right]^{1/2}$
Malmquist	$\left(\dfrac{D_t(X_t,Q_t;t)}{D_{t-1}(X_{t-1},Q_{t-1};t)}\right)\left[\left(\dfrac{D_{t-1}(X_t,Q_t;t)}{D_t(X_t,Q_t;t)}\right)\left(\dfrac{D_{t-1}(X_{t-1},Q_{t-1};t)}{D_t(X_{t-1},Q_{t-1};t)}\right)\right]^{1/2}$
	$\dfrac{\sum_{j=1}^{n} R_{jt}Q_{jt}}{\sum_{j=1}^{n} R_{jt-1}Q_{jt-1}} \bigg/ \left(\dfrac{E_t}{E_{t-1}}\right)\dfrac{\sum_{i=1}^{m} S_{it}X_{it}}{\sum_{i=1}^{m} S_{it-1}X_{it-1}}$
	$\left(\dfrac{\rho_t^{-1}}{\rho_{t-1}^{-1}}\right)\dfrac{\sum_{j=1}^{n} R_{jt}Q_{jt}}{\sum_{j=1}^{n} R_{jt-1}Q_{jt-1}} \bigg/ \dfrac{\sum_{i=1}^{m} S_{it}X_{it}}{\sum_{i=1}^{m} S_{it-1}X_{it-1}}$

Note: p refers to output prices; Q to output quantities; w to input prices; X to input quantities; R to revenue shares i.e. $P_jQ_j/\Sigma P_jQ_j$; S to cost shares i.e. $w_iX_i/\Sigma w_iX_i$; and D(·) to the distance function.

All the above TFP indices implicitly assume a long-run equilibrium, with all inputs being variable and consequently, factor rental prices are equal to their shadow counterparts. In the case where some inputs are quasi-fixed, Hulten (1986) proposed an alternative formulation of the Fisher index that takes into account disequilibrium effects. Under the assumptions of profit maximisation, constant returns to scale, and of only one quasi-fixed input, the shadow price of the latter can easily computed as a residual of profit minus total variable cost. Then, this price, instead of its rental price, is used to construct the aggregate input price based on Laspeyers index. Bureau, Fare and Grosskopf (1995) offered measures of the Hulten TFP index for the EU and US agriculture.

Another index used in the accounting approach is that of Malmquist, initially proposed by Caves, Christensen and Diewert (1982a,b), which provides measures of TFP in the presence of technical inefficiency. There are two equivalent formulas for the Malmquist TFP index, defined upon an output and an input distance function respectively, called output- and input-based measures of productivity. In the former, TFP accounts for output growth as input requirements remain unchanged, while in the latter productivity is measured as input savings for any given output level. As long as production exhibits constant returns to scale, both formulas of the Malmquist TFP index result in the same measure. For an application of the Malmquist TFP index in agriculture see Bureau, Fare and Grosskopf (1995) for the EU countries and Thirtle, Piesse and Turk (1996) for Slovenia.

The main advantage of the Malmquist index is that it enables a decomposition of productivity growth between technical efficiency and technical change. With reference to the fifth row in table 1.0, the first term refers to the contribution of technical efficiency improvement while the bracketed term corresponds to the rate of technical change, as it is depicted by an upward shift of the production function. Despite this advantage, measurement of the Malmquist TFP index requires the parametric or non-parametric estimation of the underlying distance function. This complicates its empirical use and definitely restricts the number of inputs and outputs included in the analysis, which is the main advantage of the accounting approach.

Nevertheless, computation of the Malmquist TFP index, without estimating the underlying distance function, is possible in two special cases, but at the cost of not being able to attribute the sources of TFP change (i.e., improvement in technical efficiency and technical change). First, when the distance function has a translog form and technical and allocative inefficiency are assumed away, the Malmquist TFP index can be approximated by a Tornqvist-Theil-type index. It actually becomes an ordinary Tornqvist-Theil TFP index in the special case of constant returns to scale (Caves, Christensen and Diewert, 1982a,b).

Second, under less restrictive assumptions, the Malmquist TFP index can be approximated by the ratio of two Fisher indices corresponding to aggregate output and input quantities. These assumptions are (a) profit maximisation; (b) constant returns to scale and (c) allocative efficiency (Fare and Grosskopf, 1992; Bulk, 1993). Notice that these assumptions do not imply any restrictions on the functional form of the underlying distance function neither do they require technical efficiency. Moreover, due to the assumption of constant returns to scale, the output- and the input-based Malmquist TFP indices coincide. The formula for calculating this version of the Malmquist TFP index is similar to that given in the forth row of table 1.0.

There are other ways measures of productivity that use economic techniques and linear programming. While these techniques are used by economists there seldom used to report official productivity figures i.e. most governments use the accounting approach when they report productivity. We discuss these economic approaches in some detail in appendix A and leave it to the interested student to pursue the topic in more detail if they wish.

3.3 Estimates of Agricultural Productivity in Turkey

Analysis of total factor productivity measures the amount of increase in total output not accounted for by increases in total inputs. The total factor productivity index is calculated as the ratio of an index of aggregate output to an index of aggregate inputs. Growth in TFP is therefore the growth in total output less the growth rate in total inputs. In this study, Tornqvist TFP indices are computed for the outputs and inputs in Turkish

Agriculture. Tornqvist Index is computed after determining a logarithmic (rate of proportional) change as:

$$\mathbf{\ln X_t - \ln X_{t-1} = \Sigma_i \,[\, s_i(\ln x_{it} - \ln x_{it-1})]}$$

where x_i denotes inputs. $s_{I's}$ are the cost share weights and computed as:

$$\mathbf{s_i = ½\, [\{\, c_{it}x_{it} / \Sigma_i(c_{it}x_{it})\, \}+\{\, c_{it-1}x_{it-1} / \Sigma_i(c_{it-1}x_{it-1})]}$$

exponential of this logarithmic change yields the index number. Similarly, the Tornqvist index can be formed for output. In this case x_i would denote outputs and s_i are the revenue share weights. Specifying the index to equal 100 in a particular year and finding the ratio of output to input index provides the TFP index.

The Tornqvist index is a superlative index that is exact for the linear homogeneous translog production function. A further advantage of the Tornqvist index is that it accounts for changes in quality of inputs. Because current factor prices are used in constructing the weights, quality improvements in inputs are incorporated, to the extent that these are reflected in higher wage and rental rates.

The Tornqvist index provides consistent aggregation of inputs and outputs under the assumptions of competitive behaviour, constant returns to scale, Hicks-neutral technical change, and input-output separability. However, it is also shown that Tornqvist indices are also superlative under very general production structures, i.e., non-homogeneous and non-constant returns to scale, so they should provide consistent aggregation across are range of production structures. (Caves, Christensen, and Diewert 1982a,b)

In the study productivity estimates have been made using the Tornqvist index. A total of 53 commodities out of which 10 are cereals, 9 are pulses, 12 are industrial crops, 10 are oil seeds, 12 are fruits, and 5 are nuts; are included in the output index. Farm prices are used to aggregate the outputs. Inputs included in the input index are cultivated land, labor, number of tractors, and fertilisers. The whole data set and sources of data are supplied in excel spreadsheet files as a separate Appendix.

The estimated Output Index, Input Index and Total Factor Productivity Index are presented in figures 2.0, 3.0 and 4.0 respectively.

As shown in figure 2.0, output growth has been fairly steady until 1987, and levelled of since that time. The average growth rate of output is. The average growth rate of the output is 8.2 percent in the 1967-1988 period. However, the growth rate of output declined after that period to 0.5 percent. The average growth rates yearly growth rates and of output input and TFP indices are presented in Table 3.0 and 4.0 respectively.

Figure 3.0 presents the aggregate input index in Turkish agriculture. It can be observed from the figure that Turkish agriculture uses roughly twice more inputs in 1990ies compared to 1960ies. The growth rate of inputs is steadily positive in 1967-1996 period except the crises year of 1994. Aggregate input use increased around 2.55 percent per year during 1967-1988 period. It is also observed that the growth rate of inputs declined to .55 percent after that period.

Total factor productivity growth pattern is similar to the output growth rate in the sense that the steady growth of 1963-1988 seems to level of in the present years. Perhaps the most striking result of the study is that agricultural productivity seems to decline after 1998 . Agricultural productivity declined around 0.06 percent during 1989-1996 period.

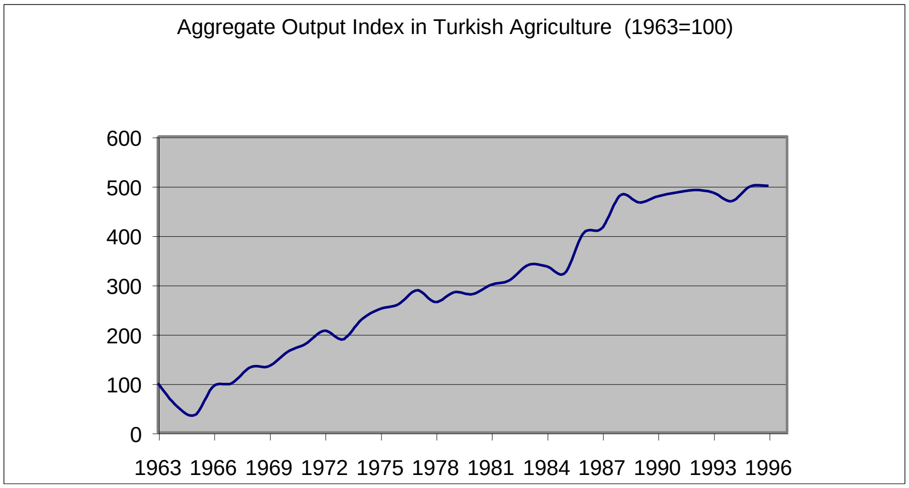

Figure 2.0

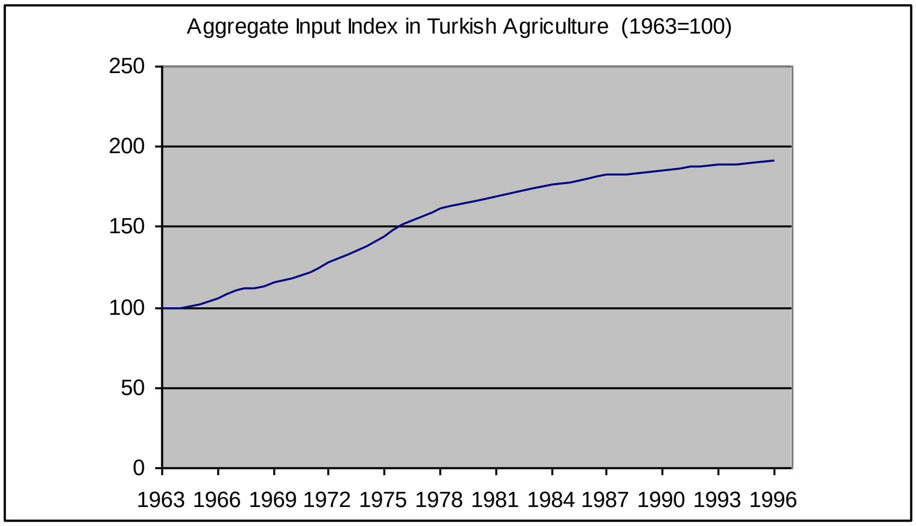

Figure 3.0

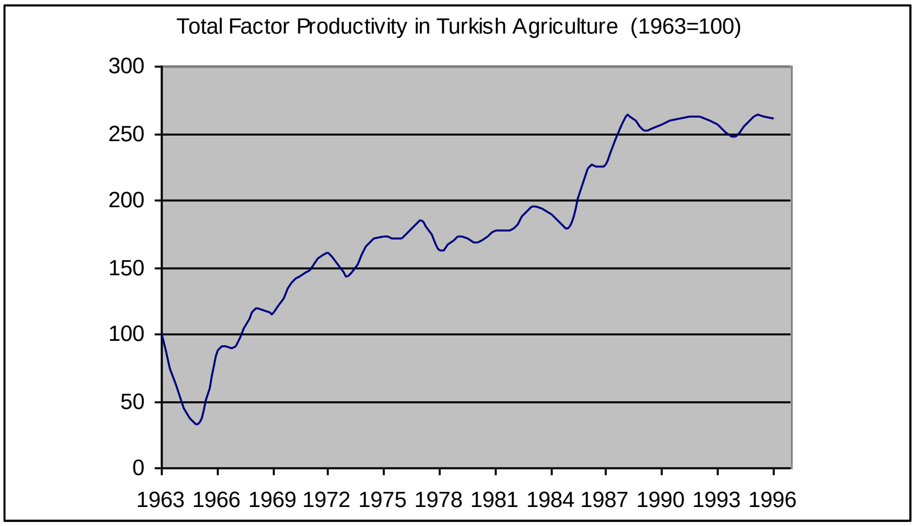

Figure 4.0

The results obtained in the study are consistent with other country estimates of TFP growths. It is very difficult to find productivity estimates that are constructed with exactly the same methodology for the same data period. In table 2.0 we have compared the agricultural productivity of the EC10 countries and the USA with our results over the period 1973-93.

Table 2.0: TFP Comparisons for Ten EC Countries and the US, 1973-93

Turkey	Belg	Denm	Irel	Fran	Germ	Gre	Ital	Lux	Neth	UK	USA	EC10
Starting Level 1973-75 average (base is EC10=100 in 1990) Turkey (base 1963=100)												
160.7	117.3	91.1	54.9	78.6	63.0	59.0	63.4	30	101.7	80.3	93.7	73.3
Final level 1991-93 Average												
260.1	147.4	138.1	77.3	128.7	87.3	77.7	93.6	37.2	139.7	105.3	156.9	106
Growth Rates, 1973-93												
2.57	1.3	2.6	1.9	3.0	1.9	1.5	2.2	1.4	1.8	1.6	3.0	1.92

Source: Schimmelpfenning and Thirle, 1997 and author's estimates

One can observe from the Table that the growth rate of agricultural productivity in Turkey is in line with the European countries when comparisons are made during the same periods. Turkey is one of the fastest growing countries in the list and it can be observed from the table is that it ranks the 4th among the thirteen countries. EC10 countries vary a lot among themselves, with the high level of productivity in countries like Denmark, France and the Netherlands, and low level of productivity in some. The most surprising in table 2.0 is the relatively low level of agricultural productivity in Germany.

It should also be noted that government subsidy payments are included in some of the productivity measures for all the countries, subsidy payments should have been excluded. This will result in an upward bias in the productivity estimates.

Table 3.0 Estimated Average Growth Rates of Output, Input and TFP in Turkish Agriculture

Year	Output Growth rate	Input Growth Rate	TFP Growth Rate
1967-96	6.16	1.99	4.07
1967-88	8.21	2.51	5.58
1989-96	0.53	0.55	-0.06

Source: Estimated

Table 4.0 . Growth Rates of Output, Input and TFP 1967-1993

	Growth rate of Output Index	Growth rate of Input Index	Growth rate of TFP
1967	6.7	3.7	3.0
1968	32.7	1.9	30.2
1969	1.4	3.2	-1.7
1970	21.5	1.5	19.7
1971	10.0	3.9	5.8
1972	14.8	4.7	9.7
1973	-8.5	3.6	-11.7
1974	21.1	4.2	16.3
1975	9.6	4.6	4.7
1976	3.6	4.9	-1.2
1977	11.0	3.2	7.5
1978	-8.5	3.4	-11.5
1979	7.7	1.8	5.8
1980	-1.3	1.2	-2.5
1981	6.7	1.4	5.2
1982	3.2	1.7	1.4
1983	10.0	1.2	8.6
1984	-0.8	1.7	-2.5
1985	-4.0	0.8	-4.8
1986	25.0	1.2	23.6
1987	2.6	1.1	1.5
1988	16.1	0.4	15.6
1989	-3.2	0.8	-3.9
1990	2.6	0.7	1.9
1991	1.7	0.2	1.4
1992	1.1	0.7	0.4
1993	-1.1	0.7	-1.9
1994	-3.6	-0.2	-3.4
1995	6.4	0.7	5.6
1996	0.3	0.8	-0.6

Source:Estimated

3.4 Long-Run Relationship Between Total Factor Productivity and R&D Expenditures in Turkish Agriculture

Increases in productivity can be induced by investments in research, extension, human capital, and infrastructure. As an input into public investment decisions, it is useful to understand the relative importance of these productivity-enhancing investments in determining productivity growth. The second part of the analysis is therefore to estimate the relationship between Research, extension and development expenditures and TFP, to assess the importance of these expenditures in TFP growth.

In order to estimate the long-run relationship, we start with a two-variable system Zt =(LNTFP,LNRD) that is postulated to explain total factor productivity in Turkey. In the system LNTFP is the natural logarithm of total factor productivity index and LNRD is the logarithm of the index for Research and Development expenditures. Since long-term data for research, extension and development expenditures were not available for Turkey the RD index is constructed by adding budgets of research institutes related to agriculture and budgets of ministry of agriculture, rural affairs and ministry of forestry. The constructed real index to indicate R and D expenditures in Turkey is presented in figure 5.0. The sample period is from 1963 to 1996, but effective estimation periods are reduced so as to accomadate the dynamic structure of estimated equations.

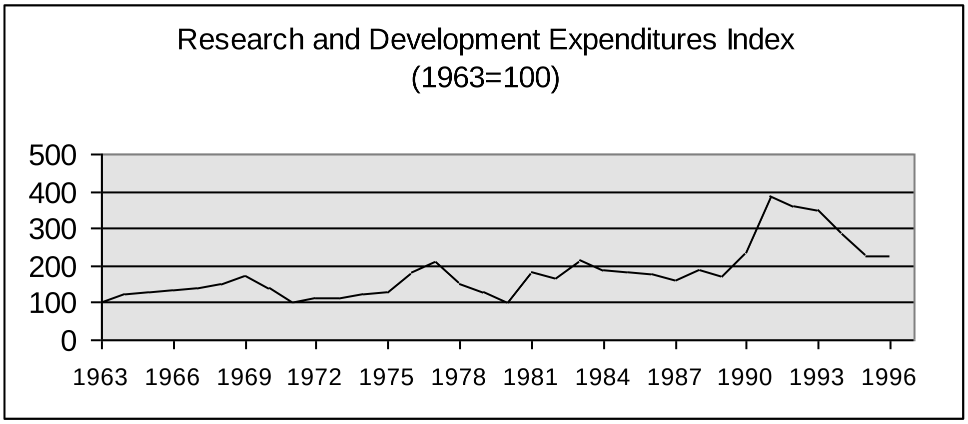

Figure 5.0

Following the recent advances in time series econometrics, cointegration procedure is employed, which is proposed by Johansen instead of OLS. One basic reason for the use of cointegration technique instead of the OLS; is the problem of spurious regression amongst non-stationary and non-cointegrated variables.

If two or more series are linked to form an equilibrium relationship spanning the long-run, then even though the series themselves may contain stochastic trends (i.e. be non-stationary) they will nevertheless move closely together over time and the difference between them will be stable (i.e. stationary). The concept of cointegration brings the existence of a long run equilibrium to which an economic system converges over time and it can be interpreted as the disequilibrium error (i.e. the distance that the system is away from equilibrium at time t)

When considering long-run relationships, it becomes necessary to consider the underlying properties of the processes that generate time-series variables. That is, a differentiation between stationary and non-stationary variables is needed, since failure can lead to a problem of spurious regression whereby the results suggest that there are statistically significant long-run relationships between the variables in the regression model when in fact all that is being obtained is evidence of contemporaneous correlations rather than meaningful causal relations.

When discussing stationary and non-stationary time-series, the need to test for the presence of unit roots in order to avoid the problem of spurious regression was stressed. If a variable contains a unit root then it is non- stationary and unless it combines with other non-stationary series to form a stationary cointegration relationship, the regressions involving the series can falsely imply the existence of a meaningful economic relationship.

In principle it is important to test the order of integration of each variable in a model, to establish whether it is non-stationary and how many times the variable needs to be differenced to result in a stationary series. Also, testing for stationarity for a single variable is very similar to testing whether a linear combination of variables cointegrate to form a stationary, equilibrium relationship. As cointegration is a property postulated for non-stationary variables, testing for the degree of integration of the individual series is often taken as a necessary pre-test for a cointegration analysis.

There are several ways of testing for the presence of a unit root. Augmented Dickey-Fuller (ADF) tests are usually chosen because they tend to be more popular either because of their simplicity or their more general nature. ADF approach is; testing the null hypothesis that a series does contain a unit root (i.e. it is non-stationary) against the alternative of stationarity.

First step for ADF approach is determining the data generating process (d.g.p). In general, since the underlying d.g.p is unknown, this suggests that using a d.g.p having both a stochastic and deterministic trend is useful for testing the unit root hypothesis.

Augmented Dickey-Fuller (ADF) tests are carried out by *Microfit 4.0.* For the ADF tests the following equation is estimated, and the results of the tests are presented in table 5.0.

$$(1)\quad \Delta yt = Bo + B1t + \alpha y_{t-i} + \sum_{i=0}^{k} \gamma I \, \Delta y_{t-i} + ut \qquad ut \sim IID(0, \sigma 2)Y$$

Ho: $\alpha = 0$ vs. Ha: $\alpha < 0$; where k is the truncation lag length.

If a variable which is differentiated of order two is stationary, the first order differentiation of it must be non-stationary; meaning there are unit roots which comes out from the solution of the non-rejection of the null hypothesis.

The results recorded in table 5.0 suggest that each of the variables in Zt is integrated of order I(1), which means that both LNTFP and LNRD non-stationary.

Table 5.0: Augmented Dickey-Fuller (ADF) Test Statistics

SERIES	Level (with trend)	Level (without trend)	First Differences
LNTFP	-3.08(3)	-2.31(3)	3.59(3)
LNRD	-3.11(3)	-1.24(3)	-4.23(3)
95% critical values	(-3.57)	(-2.96)	(-2.96)

In Johansen cointegration approach; the first step is to define a vector Zt of n potentially endogenous variables. It is possible to specify the following data generating process (d.g.p) and model Zt as an unrestricted vector autoregression (VAR) involving up to k lags of Zt:

(2) $Zt = A1\ Zt\text{-}1 + ... + Ak\ Zt\text{-}k + ut \qquad ut\ \ IN(0,\Sigma)$

where Zt is (n*1) and each of Ai is an (n*n) matrix of parameters. The system is in reduced form with each variable in Zt regressed on only lagged values of both itself and all the other variables in the system.

Equation (2) can be reformulated into a vector error-correction form (VECM): Johansen approach requires a correctly specified VECM, it is necessary to ensure that the residuals in the model are “white noise”. This involves setting the appropriate lag length in the model.

(3) $Dzt = \Gamma\ DZt\text{-}1 + ... + \Gamma k\text{-}1\ Dzt\text{-}1 + \Pi Zt\text{-}k + ut$

where $\Gamma I = -(I\text{-}A1\text{-}.......Ai)$, $(i=1,......,k\text{-}1)$, and $\Pi = -(I\text{-}A1\text{-}.......Ak)$.

This way of specifying the system contains information on both the short- and long-run adjustment to changes in Zt, via the estimates of ΓI and Π respectively. $\Pi=\alpha\beta$, where α represents the speed of adjustment to disequilibrium, while β is a matrix of long-run coefficients such that the term $\beta Zt\text{-}k$ embedded in Equation (3)represents up to (n-1) cointegration relationships in the multivariate model which ensure that Zt converge to their long-run steady-state solutions. Assuming Zt is a vector of non-stationary I(1) variables, then all the terms in Equation (3) which involve Dzt-i are I(0) while $\Pi Zt\text{-}k$ must also be stationary for ut I(0) to be “white noise”. There are three instances when this requirement that $\Pi Zt\text{-}k$ I(0) is met:

1) When all the variables in Zt are in fact stationary; there is a problem of spurious regression and the appropriate modelling strategy is to estimate VAR model like Equation(2).

2) When there is no cointegration at all; there are no linear combinations of the Zt that are I(0), and Π is an (n*n)[1] matrix of zeros. Here the appropriate model is a VAR in first differences involving no long-run elements.

---

[1] n: number of cointegrating vectors; T: sample size; k:lag-lenght

3)When there exists up to (n-1) cointegration relationships; $\beta Zt\text{-}k$ I(0). Here $r\leq$ (n-1) cointegration vectors exist in β, together with (n-r) non-stationary vectors. Only the cointegration vectors in β enter Eqn(2), otherwise $\Pi Zt\text{-}k$ would not be I(0), which implies that the last (n-r) columns of α are insignificantly small.

The method of testing for “reduced rank” is considered, which involves testing how many cointegration vectors are present in the model. This involves a discussion of Johansen’s trace and maximal eigenvalue tests.

If a model contains z_t , a vector of non-stationary I(1) variables, then $\Pi_{zt\text{-}t}$ in equation (2) contains the stationary long-run error-correction relations and must be stationary for $u_t \sim$ I(o) to be “white noise”. This occurs when Π (=$\alpha\beta$‘) has reduced rank, that is, there are $r\leq$(n-1) cointegration vectors present in β so that testing for cointegration amounts to finding the number of r linearly independent columns in Π, which is equivalent to testing that the last (n-r) columns of α are insignificantly small (i.e. effectively zero)

To test the null hypothesis that there are at most r cointegration vectors and thus (n-r) unit roads amounts to :

H_0: $\lambda_I=0$ i=r+1,......,n.

where only the first r eigenvalues are non-zero. This restriction can be imposed for different values of r and then the log of the maximised likelihood function for the restricted model is compared to the log of the maximised likelihood function for the unrestricted model and a standard likelihood ratio test computed (although with a non-standard distribution). That is, it is possible to test the null hypothesis using what has become known as the trace statistic:

$$\lambda\text{trace} = -2\log (Q) = -T \Sigma \log (1- \lambda I) \qquad r=0,1.....,n-1$$

where Q=(restricted maximised likelihood /unrestricted maximised likelihood)

λtrace statistics test the null that r=q (q=1,....,n-1) against the unrestricted alternative that r=n.

Another test of the significance of the largest λr is the so-called maximal-eigenvalue or λ-max statistic:

$\lambda max = -Tlog(1-\lambda r+1) \qquad r=0,.....,n-1$

This tests that there are r cointegration vectors against the alternative r+1 exist. Between Johansen's two LR tests for cointegration, the trace test shows more robustness to both skewness and excess kurtosis in (the residuals) than the maximal eigenvalue (λmax) test.

Briefly, the reduced rank regression procedure provides information on how many unique cointegration vectors span the cointegration space , while any linear combination of the stationary vectors is itself also a stationary vector and thus estimates produced for any particular vector in β are not necessarily unique.

Table 6.0 presents the results of cointegration analysis obtained by the estimation of the long-run relationship between LNTFP and LNRD with the lag-length of k=3. Both the maximum eigenvalue (λmax) and trace eigenvalue (λtrace) statistics strongly reject the null hypothesis of no co-integrating vector (r =0) in favor of one cointegrating vector ($r \leq 1$). So there appears to be a single co-integrating vector for the system.

Table 6.0: Cointegration Analysis for the General System

Eigenvalues	**.68836**	**.053170**
Hypothesis	r =0	$r \leq 1$
λmax	36.1428	1.6937
λtrace	37.8366	1.6937
95% (λmax)	11.030	4.16
95% (λtrace)	12.36	4.16

The long-run relationship indicated by the cointegration analysis between LNTFP and LNRD can be summarised as follows:

LNTFP = 1.0378 LNRD

This result indicates that there is a strong positive relationship between research expenditure index and total factor productivity in Turkish agriculture. The equation also indicates that the R&D elasticity of TFP is around one.

4.0 Growth Theory and Agriculture

The next question is how do we explain this growth in productivity. This has been a question that been on the agenda of research economists for a number of years. Solow (1971) estimated that one- third of the growth in U.S. output could be explained by an increase in the use of conventional inputs with the remainder unexplained. He then went on to hypothesis that technological change was the major contributor to the growth in U.S. output. If we assume a similar situation exists in Turkey, this leaves us with the question as to what causes technological change.

Ruttan (1997) reviewed the current growth theories that included i) the induced technical change, ii) evolutionary theory, and iii) path dependence. (We will not discuss these theories as it is beyond the scope of this text, however the interested student can read Ruttan,(1997)) The induced technical change literature has explained growth through demand-pull models (Griliches), the stability in factor shares and a microeconomic model of changing relative factor prices *a la* Hicks. The evolutionary model is based upon the work of Nelson and Winters where they develop a model that suggests innovators i) search for local innovation, ii)imitate the practices of other firms they observe, and iii) use a satisfying objective function rather than profit maximisation. The path dependence model assumes firms innovate along a given trajectory and once they get locked in on one type or model they can’t change.

The policy followed by most developed countries to achieve economic growth in agriculture is to invest in RD. In fact countries, like Canada, USA and EC10 all have large research budgets i.e. taxpayer funds, as well they encourage the private sector to invest in research. This is generally seen as the major policy tool to increase productivity growth. By investing in R&D governments and private firm seek new ideas to solve problems or develop new products (Romer, 1995).

5.0 Research Institutions

We often speak of research institutions like government experimental stations or universities. In this report we have reserved the word institutions for those arrangements that are viewed as norms in society like property rights. There are many institutional arrangements that effect agricultural research and we will discuss them in some detail. When we speak of research organisations we are referring to how research is organised in the economy. We will discuss this as well.

When examining the question of research expenditures and productivity growth the most important institution is property rights. When new technology is developed it is important to know who has the property rights to the technology and how they are enforced. If a firm develops a new technique but can not exclude others from using or selling the same technology they will have no incentive to make the investment. In economics we often distinguish between technology that is embodied and disembodied where embodied technology is technology that is embodied in a product that is sold i.e. machinery. Disembodied technology is a technology that is not part of any particular good. An example of disembodied technology would be agronomic information. It is generally easier to exclude the use of embodied technology than disembodies technology.

Countries have laws that protect new technologies, called patent laws. If a company develops a new technique or product it can apply for a patent which, when granted, means other companies can only use the new technology if they pay the inventor. If a country has weak enforcement of such laws, companies will not invest in the development of new technologies and may go as far as refusing to sell their products in such countries. However, for some new agricultural products like crop varieties it is almost impossible to protect new varieties from being sold between farmers thus cutting out the developer of the new variety. For this reason most of the early plant breeding was done by the government with the new varieties released free of charge to producers.

As governments became short of funds to spend on agricultural research they sought ways to increase the enforcement of property rights for new crop varieties. Of course the most simple process to protect property rights is through the process of hybridisation. Plants in which hybrid vigour could be developed were attractive to private investors because it was a means of protecting their property rights to the technology as well as achieving large yield increases. They simply had to keep the parent plants (i.e. F1 generation) confidential. Corn was one of the first field crops to be adapted to this type of research and today all corn research is done in the private sector.

Over time other crops such as vegetables and flowers have also developed hybrid technology. Many animals such as poultry have also succeeded in this hybridisation process with the same result that the research investment is now done in the private sector.

However many crops can not use the hybridisation process and were left to the public sector to fund. Governments and business both found this to be less than optimal because the government did not want to invest in agricultural technology. A number of pieces of legislation have been passed by the government to expand to property right reach of the private sector. Currently the WTO is trying to introduce trade rules that protect intellectual property rights on traded products. This will have a major impact on agricultural technology that is transferred such as new crop varieties. These are complicated and controversial issues but they both are used to provide the private sector greater incentive to invest in agricultural research.

Another important issue here is the transfer of technology between countries. Two countries like Turkey and Iran have some very similar growing regions and one would expect that the technology used in one country would be readily adopted in the other country. This is often the case, however if the technology is protected through patents in one country and not the second, then the lack of an appropriate institutional structure can block technology transfer between countries. As companies often invest and do business in both countries this can be very inefficient.

One of the new and most promising areas of agricultural research is biotechnology. This research deals almost exclusively with life forms and is very powerful in the type of changes it can introduce. New technologies include, improved drugs, improved crop varieties and modifications to animal genetics to mention only a few. Some of these technologies are likely to be very profitable in the future. There are at least two parts to Biotechnology that are worth protecting for a private company, i) the technique in making the transfer of genetic material, and ii) the material that is effected. Without making itself available to all the potential technology in the world Turkish farmers will find their productivity levels and incomes fall behind those of its competitors who do adopt the new technology. We discuss the benefits and costs to producers later on in this report.

6.0 Research Expenditures in Turkish Agriculture

Who makes the expenditure on agricultural research and who has the property rights to the new technology are closely linked. The private sector will not invest their scarce resources on investments that its competitors can benefit from directly without any payment. These technologies(non rival and non excludable) are considered to be in the public sector i.e. public goods and the investment is made either by the governments or by producers themselves. More research is becoming jointly funded between the private and public sector, for example the private sector using government labs and expertise. However there maybe a problem with these types of arrangements as we shall soon discuss.

Who makes the expenditure on agricultural research and who has the property rights to the new technology are closely linked. The private sector will not invest their scarce resources on investments that its competitors can benefit from directly without any payment. These technologies are considered to be in the public sector i.e. public goods and the investment is made either by the government or by producers themselves. More research is becoming jointly funded between the private and public sector with the public sector providing grants and laboratory space with the private sector providing the remaining costs.

A series of government expenditures on agricultural research is shown in figure 6.0. Expenditures increased around 1974, 1981 and rose sharply in 1991 before falling back to 1980 levels. (All figures are in TL, 1963=100). These expenditure figures are for the total ministry of agriculture in Turkey and thus do not represent the magnitude of investments in research and extension. It is possible the fluctuations in expenditures for the totals ministry are representative of the research expenditure pattern and thus may be useful from that perspective. Much of the seed research was associated with the state farms system in Turkey. However, in recent years the budgets for state farms has been collapsed into the overall ministry budget as the importance of state farms has been reduced.

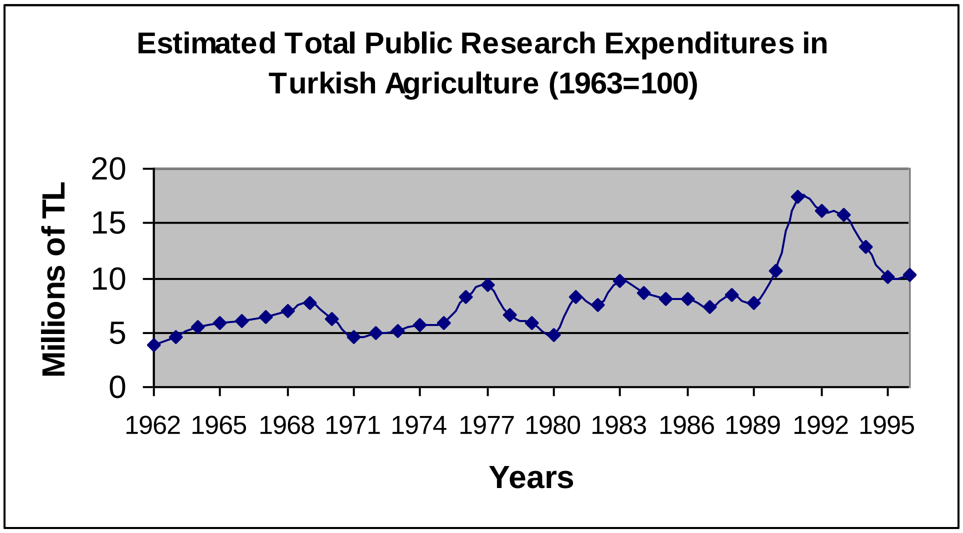

Figure 6.0

In order to get some estimate of the wheat and cotton research expenditures we used the revenue weights for each of the respective crops. And applied these weighs to the overall ministry budget. Wheat for example makes about 5% of all field crop and tree fruit revenue; cotton makes up .5%. The assumption made then is that the government funds research in the same priority as the crop is to overall crop and fruit revenues. While this is rough justice it is probably not far off the mark. After discussing this with Turkish experts it was agreed this to make the best available approximation. (In our analysis we increased wheat research costs to 30% and cotton research costs to 10% of the ministry budget.)

Using the above approximation we estimated the expenditures for wheat and cotton research, which are shown in figures 7.0 and 8.0.

The Turkish government is not increasing its support for agricultural research and the private sector appears to be picking up some of the slack. Most of this research is for crops and vegetables that are protected through hybrid varieties such as cotton. The data in table 7.0 provides an estimate of the private expenditures on agricultural research and development.

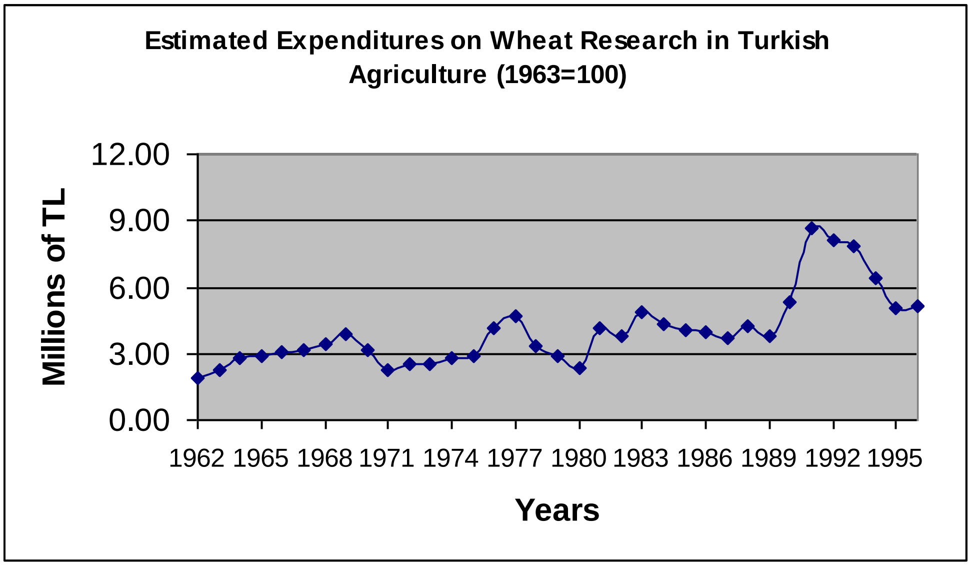

Figure 7.0

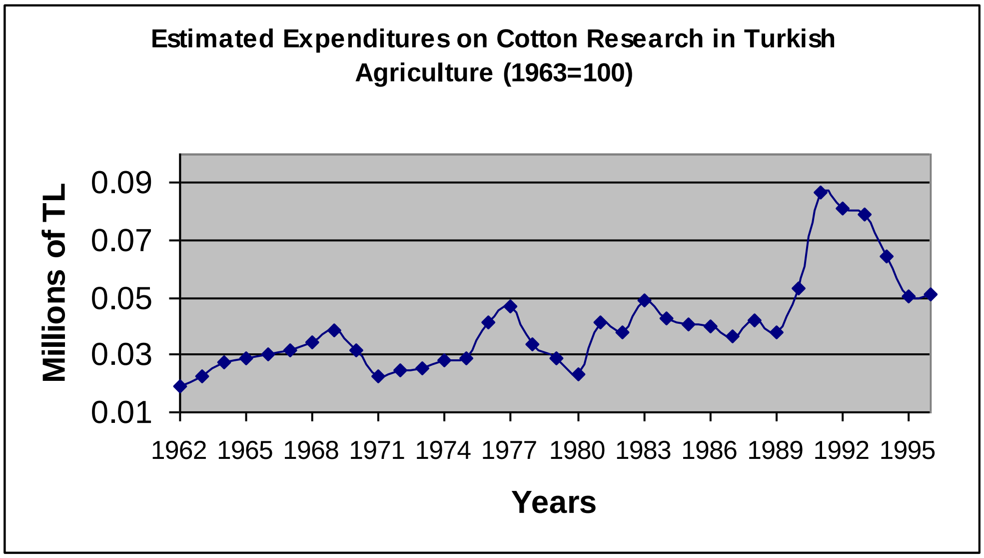

Figure 8.0

Table 7.0 Private agricultural research expenditures in Turkey 1992-95

Year	Amount in Million. TL (undeflated)
1992	1 286 951
1993	2 010272
1994	3 454 939
1995	6 966 948

Source Yearbook of Turkey, 1997

A number of interesting policy questions that arise when we discuss who should fund agricultural research. Often economists argue that the beneficiaries of the research should be the one who should make the investment. This leads to the question of who does benefit. In the past most analysis showed that both consumers and producers benefited, however this answer is very sensitive to the model that is chosen by the economist. Clearly such large public investments need to be evaluated to determine what the taxpayer is receiving for the dollar invested.

7.0 Evaluation of Research Expenditures

There are few topics that have received such attention and the answer being so conclusive as the economic evaluation of public expenditures on agricultural research. Griliches in his early work on the benefits of hybrid corn in the U.S. estimated the return to be in the range of 700%. This was followed by a large number of studies that duplicated this approach, plus used other methodologies and found similar results as to the rate of return to research, these have been summarized by Ruttan and Alston, Norton and Pardy. In Canada a number of studies have been done with similar results, see Klein and Furtan. One question that remains is why the rate of return to agricultural research remains so high.

The economic analysis to date has used economic models that are largely free of any government distortions and assume perfect competition. It is useful to examine the assumptions and the differences these make in our conclusions regarding the benefits of

R&D expenditures. First, what happens when we have a small economy like Turkey, and second when the markets are distorted with government subsidies. All of these conditions have the potential to greatly change the estimated return on research expenditures. For many commodities Turkey trades in an open economy, however because of border measures such as taxes and tariffs Turkey often has a closed economy, like cotton. As well, these markets are at times distorted due to government subsidies of one kind or another. Private companies, make large investments in agricultural research on joint projects with the government, thus we must consider private returns and to public investments as well as public costs and returns.

This section develops a simple model of estimating returns to research using consumer and producer surplus. Other methodologies exist and are used y economists but we will not develop them in detail in this chapter. Readers should consult the book by Alston, Norton and Pardy, which reviews the methodologies in detail. In this section, we also examine the question of how international trade effects returns to R and D expenditures, as well as the effects of market distortions caused by government subsidies. Finally, using the example of Ulrich, Furtan and Schmitz, we show how one can calculate the returns to private investment on joint research.

7.1 The Basic Model

Consider the case where we have only public investment in research that results in a publicly available new technology. Let the cost of the investment be I_0, and after a period of time, a new technology is made available to farmers. This process is shown in figure 9.0. For a closed economy, with linear supply and demand curves, and assuming a parallel shift in the supply curve (see Alston, Norton and Purdy for a discussion of supply shifts). We see that there are two effects of this investment: first an increase in real income or consumer surplus, and a change in returns to the fixed factors of production, or producer surplus.

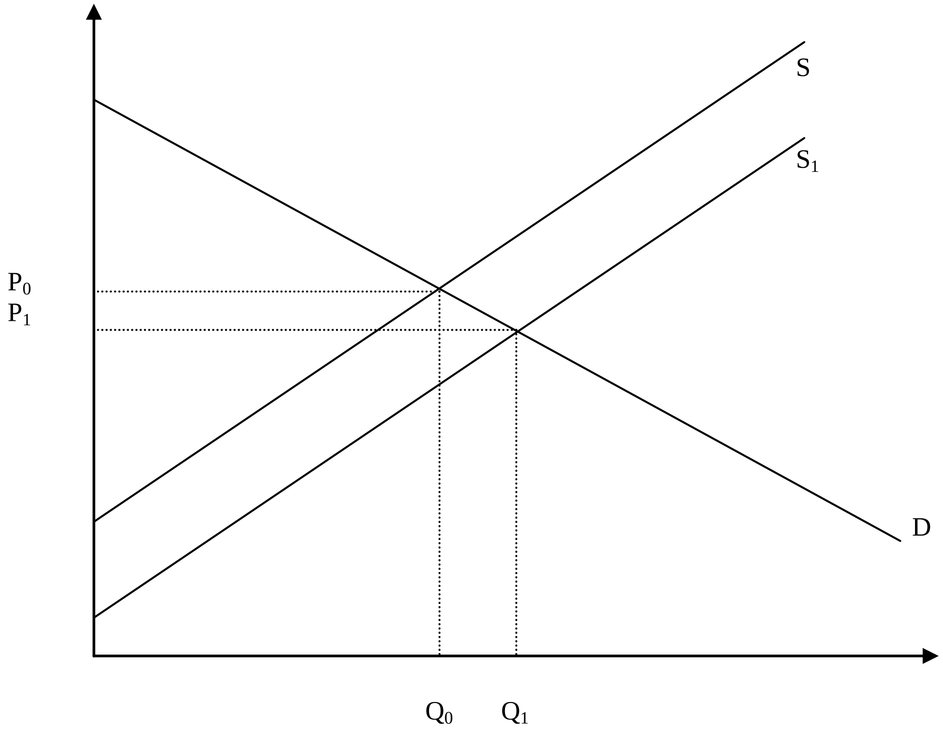

Figure 9.0 Supply Shift due to New Technology

If we sum the returns (positive and negative) into B_i , i = 1… n, for n periods, we can calculate the returns on the investment I_0 as:

$$(1) \qquad I_0 = B_0 + \frac{B_1}{(1+r)} + \frac{B_2}{(1+r)^2} + ... + \frac{B_n}{(1+r)^n}$$

To empirically use this model we must be able to calculate the benefits from research, which is a difficult task. If we think of new crop varieties, we must know how much they increase yields, how much farmers adapt the new varieties and whether or not additional inputs such as fertiliser and chemicals are required.

Most research in agriculture is an on-going process and can not be adequately described as a one-time investment as in equation (4). In such a case, economists have used the net present value formula:

$$(2) \qquad NPV = \frac{\sum_{i=1}^{A}(B_i - C_i)}{(1+r)^i}$$

where: B_i is as in equation (1) and C_i is the cost incurred in period i. Also, the technology developed may decay or depreciate over time, meaning the benefits and costs need to include a depreciation allowance (see Alston et. al.).

Finally, the internal rate of return on the investment in new technology can be calculated from equation (5) by solving for that value of r which makes the NPV=0. The assumptions required to make the internal rate of returns unique are quite strong (REF), it is used nevertheless.

7.2 Effects of Trade and Distorted Markets on R and D

In this section of the chapter, we examine what effect international trade and subsidies have on the estimates of returns to agricultural research. For readers who wish to examine the international effects alone, they should read the paper by Edwards and Freebairn (1984) or Alston et al. Because, even after the 1995 GATT, many of the international markets are subsidised, it is important to incorporate these effects. The policy implications for agricultural research in some developed countries for commodities like wheat are far reaching.

In this section, we consider only the case of a parallel supply shift resulting from a technological change. In figure 10.0, the domestic supply and demand schedules are S_0 and D_d respectively.

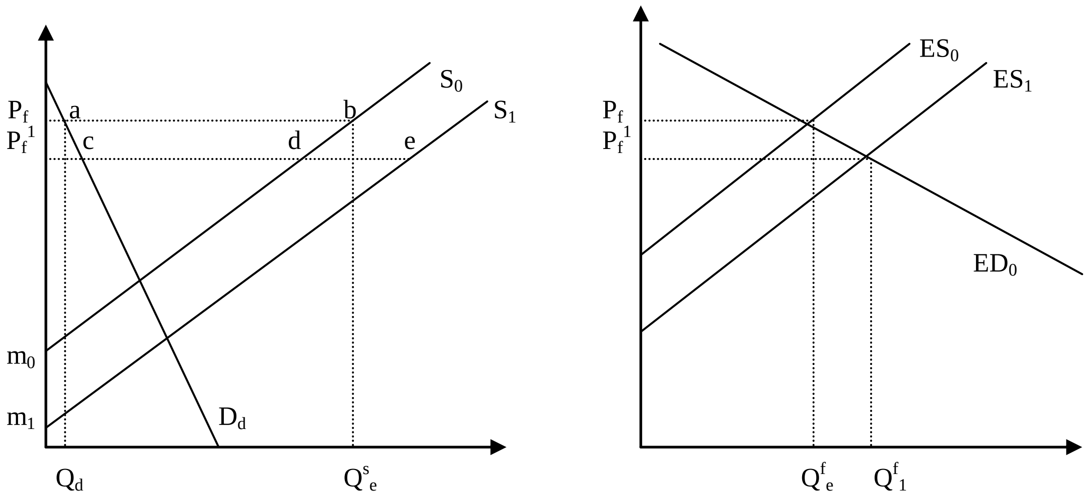

Figure 10.0 Research Returns under Trade For the Large Country Case.

The corresponding excess supply schedule is ES_0, while the excess demand curve facing the country is ED_0. These give a free trade price of P_f and exports of Q^f_e. In the domestic market, the production level is Q_e^s and domestic consumption is Q_d. If we now shift the domestic supply curve from S^0 to S^1 (due to a technological change), the corresponding excess supply shift is from ES_0 to ES_1 and the resulting world price and quantity traded are P_f^1 and Q_f^1.

The gross annual research benefit (GARB) can be calculated in the domestic market. Domestic consumers gains area $P_facP_f^1$, a transfer from producers, while producers gain the net of area m_0dem_1 less area $P_fbdP_f^1$. Given this free trade market, both the producers and consumers will benefit from the new technology.

The one assumption made in the above analysis is the technology that is made available and adopted in the domestic market, is not adopted by the other exporters (see Edwards and Freebairn). If the excess supply curve is made up of more than one exporter, the effects of the new technology on other countries' production costs must be accounted for in the analysis. For example, if the excess supply curve is made up of two exporters with identical domestic market demand and supply curves, we get the situation depicted in figure 11.0.

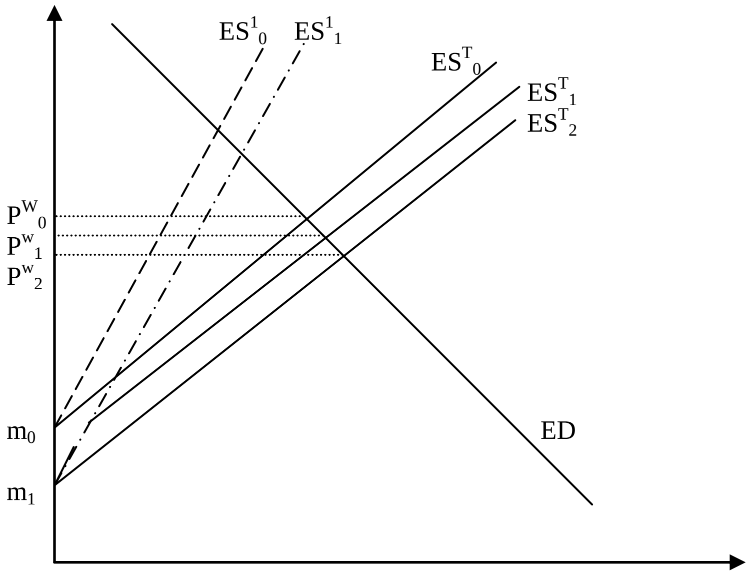

Figure 11.0 Returns to Research with Multiple Exporters

The total excess supply is the horizontal sum of the excess supply from each country, thus ES^T_0=ES_1+ES_2 for country 1 and 2 respectively. Given excess demand ED, we get equilibrium price P^w_0. Suppose now the new technology is only adopted in country 1, shifting country 1's supply curve in a parallel fashion (from ES^1_0 to ES^1_1). The new excess supply curve is ES^T_1, with a kink where country 2 starts to export. The new technology equilibrium price is P^w_1. Finally, suppose the new technology developed in country 1 s fully adopted in country 2. The new total excess supply curve is $ES^T_{2.}$. In this final case, the price falls to P^w_2.

Benefits to producers in country 1 depends upon the magnitude the elasticity of the demand and supply curve in each country and the market share each country. From this framework, Edwards and Freebairn calculated the "breakeven" values of the parameters for country 1 to benefit from cost reducing research. In their analysis they made the assumption that subsidies were not present in the market. We will now turn our attention to the effect of subsidies on the benefits of research.

If government subsidises exports, then the cost of the subsidy must be accounted for when determining GARB from cost-reducing agricultural research. As many, if not most, developed countries have used, or are using agricultural subsidies, Schmitz, Sigurdsen and Doering, 1986, demonstrated that the cost of the domestic subsidy may be larger than the additional benefits gained from adopting cost-reducing research. Later, Murphy, Furtan and Schmitz, 1993, developed a rigorous mathematical model to compare the GARB from research when subsidies are present. We will now examine the model by Murphy, Furtan and Schmitz 1993.

In figure 12.0 the domestic supply and demand schedules are S_0 and D_d, respectively. The corresponding excess supply schedule is ES_0, while the excess demand curve facing the country is ED_0. These give a free trade price of P_f and exports of Q^e_1. The affect of an internal price supported at P^s by means of export refunds (subsidies) is to increase exports to Q^e_0 and cause the export price to fall to P^w_0.

The cost of the export refund is abcd. Suppose supply shifts to S_1 because of R and D, causing the excess supply curve to shift to ES_1. In the domestic market, the increase in producer surplus (ΔPS) is m_0bhm_1. Since exports increase to Q^e_1, the cost of export refunds rises to ahkl. Thus, the increase in export refund payments (ΔER) is dcbhkl.

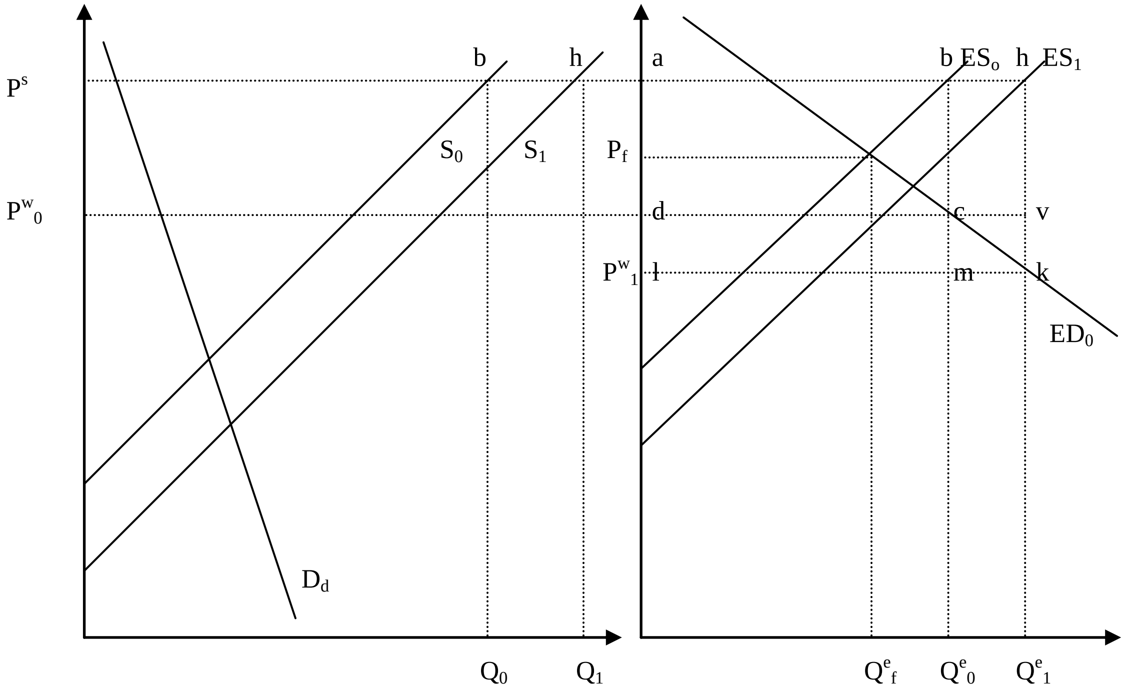

Figure 12.0 Gains from research under distorted trade

Zero or Negative GARB

The conditions which give rise to zero gains from research can be assessed by setting $\Delta PS = \Delta ER$.

Let the intercept change for the domestic supply curve be represented by

(6) $P^s - m_1 = \delta(P^s - m_0)$, $\delta > 1$,

where m_0 and m_1 are the pre and post research intercepts respectively. It also follows that, since S_1 and S_0 are parallel, $Q_1 = \delta Q_0$ and the increase in supply is $(\delta-1)Q_0$. Then

(7) $\Delta PS = \frac{1}{2}(\delta^2-1)Q_0(P_s - m_0)$.

The increase in export subsidies can be viewed in two parts. The first allows for the rise in quantity exported but holds the world price at its initial level, P^w_0. The extra subsidy cost in that case in given by the area bhvc. This is equal to

(8) $(\delta\text{-}1)Q_0(P^s\text{-}P^w_0)$

The second is represented by the area dvkl and is due to the drop in P^w. The latter can be written as

(4) $\Delta P^w = \dfrac{\Delta Q}{Q^e_0} P^w_0 f$

where Q^e_0 is the original quantity exported, P^w_0 is the original export price, and f is the world price flexibility coefficient measured at point c on the excess demand curve (ED). Rearranging (8) gives

(10) $\Delta P^w Q^e_0 = \Delta Q P^w_0 f$

If ΔP^w and f are treated as positive values, the left-hand side of (10) is equivalent to the area dcml. Expanding this by the proportion Q^e_1/Q^e_0 gives the area dvkl.

(11) $dvkl = \Delta Q P^w_0 f Q^e_1/Q^e_0 = (\delta\text{-}1)Q_0 P^w_0 f \delta^1$,

where δ^1 is the proportionate increase in exports ($=Q^e_1/Q^e_0$) and δ is as defined above. Setting $\Delta PS=\Delta ER$ for zero gains in research gives (6)=(8)+(11), i.e.,

(12) $\frac{1}{2}(\delta\text{-}1)Q_0(P^s\text{-}m_0)=(\delta\text{-}1)Q_0(P^s\text{-}P^w_0)+(\delta\text{-}1)Q_0P^w_0 f\delta^1$

Noting that $(\delta^2\text{-}1)=(\delta+1)(\delta\text{-}1)$ and dividing through by $(\delta\text{-}1)Q^0$ gives

(13) $\frac{1}{2}(\delta+1)(P^s\text{-}m_0)=P^s\text{-}P^w_0(1\text{-}f\delta^1)$

Since $\delta(P^s\text{-}m_0)=P^s\text{-}m_1$ (see (6) above), the left-hand side is equivalent to $P^s\text{-}M$, where M is the average of m_0 and m_1. Thus, the breakeven is where

(14) $M=P^w_0(1\text{-}f\delta^1)$

or

(10) $\dfrac{P^w_0}{M} = \dfrac{1}{1-f\delta^1}$

Positive returns to research will be obtained if

(16) $P^w_0(1-f\delta^1) > M$

This condition is likely to be met if P^w_0 is high relative to M and/or the export demand curve exhibits low price flexibility. On the other hand, the lower P^w_0, or the higher *f*, the greater the export subsidy bill, and negative returns will be reached if

(17) $P^w_0(1-f\delta^1) < M$.

This result can be applied from a number of standpoints. For example, (a) for a given scenario, which could be determined at the outset of a research program, i.e. for given values of M, δ^1 and P^w_0, how long must *f* be if positive returns to research are to be obtained; or (b) if *f* is known, then, for if it is known that f=0.1 and a research project resulted in δ^1=1.25, then P^w_0, according to (14), must exceed M by at least 14.29 percent to show a positive return on that research.

(13) $$\frac{P_0^w - M}{P_0^w} = f\delta^1$$

The left-hand side ratio is the inverse of the price elasticity of supply $(E_s)^3$ in the home market, evaluated at P^w_0 and averaged over S_0 and S_1. Since f=1/E_d, where E_d is the price elasticity of ED in absolute terms and evaluated at P^w_0, then (12) can also be written as

(19) $E_d/E_s=\delta^1$

If the ration of the two elasticities exceeds δ^1, positive returns to research will be achieved.

Other effects on GARB

Using this model, one can show the effect of changes in many parameters including, for example, a change in the level of protection. Let the excess demand curve be represented by

(20) $P^w = K-DQ_e$.

The level of protection, therefore, can be influenced by changes is K, D, and P^s. To analyse the effect of each, it is convenient to partition the gain from research in a slightly different manner than that used in arriving at eq. (12). The first component, as before, is the gain in producer surplus, m_0bhm_1. The increase in export refunds, however, can be seen as the net of two components: the cost of the extra exports $Q^e_0bhQ^e_1$, and the increase (or decrease) in revenue from the world market, i.e. the difference between $olkq^e_1$ and $odcQ^e_0$. Let the three components be denoted as ΔPS, ΔCOS and ΔREV respectively, so that the gain from research can be written as

(21) $\quad GARB = \Delta PS - \Delta COS + \Delta REV$

Only ΔREV is affected by changes in K and D. This can be written as

(22) $$\begin{aligned} \Delta REV &= TR_1 - TR_0 \\ &= MR^* \Delta W \\ &= (k - 2DQ^{e*})\Delta Q \end{aligned}$$

where TR_0 and TR_1 represent the pre and post research export revenues and MR^* is the marginal revenue evaluated at Q^{e*}, the average of the pre and post research export quantities. Differentiating with respect to K and D gives

(17) $$\frac{\partial \Delta REV}{\partial K} = \Delta Q$$

and

(18) $$\frac{\partial \Delta REV}{\partial D} = -2Q^{e*}\Delta Q$$

From these results it can be concluded that, for a rise in the level of ED, there is a linear increase in GARB and for a rise in the slope of ED (i.e. a rise in D), there is a linear decrease in GARB.

The analysis of the effect of P^s is complicated because all three components of GARB may be affected. However, in the case of a parallel supply shift, the effects of ΔPS and ΔCOS in (15) are exactly offsetting. This is because $\Delta PS = \Delta Q(P^s - M)$ and $\Delta COS = \Delta QP^s$ so that the derivative with respect to P^s equals ΔQ in each case. Thus

(19) $$\frac{\partial (GARB)}{\partial P^s} = \frac{\partial (REV)}{\partial P^s}$$

Recalling (16) and noting that with the parallel supply curves, ΔQ remains constant as P^s

(20) $$\frac{\partial GARB}{\partial P^s} = -2DG\Delta Q$$

is increased

where G is the slope $\delta Q^e/\delta P^s$ of the excess supply curves.

This result shows that there is a linear and negative relationship between GARB and P^s. Intuitively, one might have expected that if P^e is to have a negative effect on GARB that effect should be at a minimum with P^s in the region of the pre and post research world price levels. From (26), however, it is clear that proximity to free trade does not have a beneficial effect on the returns to research in this case.

The first derivative in (7) also shows that the greater the slope if the ED curve (the higher D), the more GARB is negatively affected by a rise in P^s. The more price-responsive the excess supply, the greater the negative impact of P^s and the larger the supply curve shift, the more negative the impact.

8.0 Returns to Joint Public and Private Agricultural Research

There has been an increase in research the agricultural research carried out by private firms in Turkey. Many times, however, the research is done jointly between governments or universities and private industry. Around the world, as well as in Turkey, governments are entering into agreements with the private sector to carry out agricultural research. In the section we provide a methodology to evaluate joint research investments.

To estimate rates of return to investment in research, we distinguish between private and social rates of return from different types of research (eg. public, private and joint). We define (with the time subscripts deleted) the average social rate of return from investment, in a subset of industries, as

$$r_s = \frac{\sum_{i=1}^{n} \Delta C_i + \sum_{i=1}^{n} \pi_i}{Is + \sum_{i=1}^{n} Ip_i}$$

where:

ΔC_i = change in consumer surplus in industry i, the industry in which the R and D investment occurs,

$\Delta\pi_i$ = change in producer surplus or quasi-rents in industry i

Is = amount of public investment

Pi = amount of investment from industry i, and

n = number of industries experiencing a change in quasi-rents or producer surplus as a result of the R and D

Similarly, the private rate of return to the T^h industry can be defined as:

$$rp_i = \frac{\Delta\pi_i}{Ip_i}$$

and the private rate of return on public investment:

$$rs_i = \frac{\Delta\pi_i}{Is}$$

We now define three cases where the rate of return to agricultural research can be calculated. They are:

Pi = 0, Is > 0 or pure public investment

Is = 0, Pi > 0 for some i, or pure private investment

Is > 0, Pi > 0, n > 1 or joint private-public investment

From this model we see that for joint venture research both the public and private sector benefit from the others investment. In many joint venture projects the investment and benefits are not equally distributed between the two sectors and often one sector benefits more than the other.

9.0 Estimated Returns to Research for Wheat and Cotton in Turkey

One of the most agreed upon results in economics is the high return to agricultural research. This agreement has come from the large number of empirical studies that have estimated the returns to agricultural research. Ruttan (1978) was one of the first to draw this conclusion and documented the estimates. Schultz argued that when technology is changing there are opportunities for putting inputs and outputs together in a different fashion that creates the opportunity for higher than market returns.

In this report we examined two crops that are an important part of the Turkish agricultural sector; wheat and cotton. For example, wheat makes up approximately 35% of the revenue from crops. Because of the importance of these two crops and because no studies have been previously being done in Turkey this study tackles an important question for the Turkish government, how important is agricultural research.

The methodology used to estimate the return to research follows that set out in Alston et. al. and used in numerous previous works. We first estimated the change in wheat and cotton yields and then using a closed economy model estimated the returns to the research expenditures. The demand and supply elasticity estimates are given in the data appendix along with the research expenditure data.

The yield increase in wheat for Turkey has been estimated by Zencirci et. al. and reported in table 8.0. This table suggests that the increase in yield due to improved cultivars were approximately 1% in the period 1972-91. No doubt some of this yield increase was due to the CGIAR system that produced the high yielding varieties. Also it is difficult to know how much of the potential increase has made its way to the farmers fields, however the data on release of new crop varieties suggest that farmers did have a

Table 8.0 Genetic advance of bread wheat cultivars' yield per year in Turkey

Era	Yield	Range	Genetic Advance/year	
	(kg/ha)	(kg/ha)	(kg/ha)	(%)
1932-51	2187+/-996.8	1483+/-2981.6	19.05	0.85
1952-71	2276.4+/-905.3	801.9+/-643.6	44.69	1.95
1972-91	3219.8+/-1202.7	2190.3+/-5539.5	29.74	0.9
average			31.16	1.23
total			1869.6	74

Source: Zencirci, N, E. Kınacı, A. Atlı, M. Kalaycı and M. Avcı., Wheat Research in Turkey, 1998. In (H. J. Braun et. al. eds.), Wheat: Prospects for Global Improvement, Kluwer Academic Pub., Boston.

continuos flow of new crop varieties. The data on new crop varieties is also given in the appendix for the period 1981 to 1996 which is the data available.

Some agronomy experts in Turkey claim that there has been no increase in yields for the past 4-5 years, and a very slow rate (below .8%) in the past few years. There claim is that farmers have not received the appropriate information regarding new crop varieties, poor agronomic practices and problems with soil erosion. All or some of this maybe true and as a result we lower our yield gains to .5% per annum in some of our estimates. However, it must be remembered that this is a long run analysis and that we are calculating an average return over the period of time and not the rate on the past few years.

The estimates for cotton yield increase were not available from publication thus we had to rely on the option of authorities. The yield increase for cotton was about 25- 30% over the period 1972-96, however much of this must be due to fertilizer use. An estimate of 1-2% per year was suggested so we took the lower of the two figures and assumed a 1% and .5% annual increase in yields.

The estimated supply and demand elasticise for wheat and cotton are reported in table 11.ss. These estimates are very inelastic, however they are in line with FAO estimates. The demand elasticity for wheat and cotton was (.5,.7) respectively and for supply elasticity (.3,.4) respectively. The data and source for these estimates are provided in the disk that accompany this report.

Using the above estimates of the shift in supply and the estimates for demand and supply elasticity we then calculated the changes in economic surplus generated in the economy due to the research effort. The results along with some sensitivity analysis are presented in table 9.0.

Table 9.0 Estimated returns for wheat and cotton research in Turkey and Pakistan

Commodity	Assumptions	Country	Authors	IRR
Wheat	Yield increase of 1%, budget 5%	Turkey	Ours	67%
Wheat	Yield increase of .5%, budget 5%	Turkey	Ours	56%
Wheat	Yield increase of .5%, budget 50%	Turkey	Ours	32%
Wheat		Pakistan	Nagy(1996)	137%
Cotton	Yield increase of 1%, budget .5%	Turkey	Ours	277%
Cotton	Yield increase of .5%, budget .5%	Turkey	Ours	245%
Cotton	Yield increase of .5%, budget 10%	Turkey	Ours	124%
Cotton		Pakistan	Nagy(1996)	101%

Source: Nagy, J, G, and M, A, Quddus, 1996. National Level Agricultural Commodity Research Priorities for Pakistan, Report No. ARP-II(Federal), World Bank. For Nagy we report the estimated returns to maintenance research.

The assumptions we made on the return estimates were as follows. First we assumed as 8 year lag in research expenditures, that is eight years after the expenditure was made the benefits we assumed to flow. In the case of wheat we allowed the benefit stream to continue 6 years after the research investment stream stopped, while for cotton we allowed for no continued research stream. Also we assumed the closed economy case as

Turkey does not trade much of either wheat or cotton and has maintained higher domestic prices to producers through price supports.

In the case of wheat the estimates ranged between 32% and 67% and for cotton 124% and 277%. The difference is that for cotton the government has invested very little money in research and because of the higher value of the crop. However our observation is land values are very high for cotton in parts of Turkey and have increased in recent years. For cotton we found that producers received 70% of the gains from research but for wheat it was consumers who got 70% of the overall benefits. Many of the consumer benefits were captured by governments because of the price support schemes in place.

One could argue that because of the distortions in the Turkish wheat and cotton sector the benefits are over estimated. This should not be the case because of the lack of trade and so it is more a matter of distribution of the benefits. As pointed out earlier in this report the benefits are lost through trade effects and not in the domestic market.

The estimates that we found for Turkey are close to those provided by Nagy and Quddus for Pakistan. Pakistan is a developing country in the same region as Turkey so the comparison maybe useful. Nagy and Quddus found higher returns for wheat and lower for cotton.

10. Conclusions

The Turkish economy is dependent upon the agriculture sector as a source of employment and economic growth. Agriculture makes up about 40% of the Turkish economy and as such is very important. The productivity growth of the sector is extremely important if the government wishes to have food prices not increase for a population that is growing at approximately 3.5% per annum.

This paper reviews the current economic methods for estimating agricultural productivity. We then proceed to estimate the growth in Total Factor Productivity (TFP) for the period 1962-97. We made a detailed search of input use and output production for the period (all Data is reported on a disk). Much of this data has not been brought together before or the Turkish sector.

We then estimated the TFP using the Tornqvist index. Our results show that the TFP increased at an annual rate of 4% over the entire period. However when we examine the period 1962-88 the growth was 6% and from 1988-96 growth rate was -. 6%. This lower growth rate suggests that the productivity growth in the sector has stopped a major concern for the Turkish government. We also found that the TFP index and Research an Development index in Turkish agriculture are cointegrated. The econometric estimation yielded a long-run Research and Development expenditures elasticity TFP around unity.

Within agriculture two of the most important crops are wheat, the staple commodity, and cotton which is the most important industrial crop in the country. Cotton is used by the textile industry, which is a large employer of labor in the Turkish economy. The Turkish government cares out yield increasing research in both of these crops. Therefore they were chosen as two examples of were we could calculate the rate of return to agricultural research, something that has not been done for a part of the Turkish agricultural sector.

Our estimated internal rate of return (IRR) for wheat research was 67% and for cotton 143%. After reducing the yield increase by fifty percent the IRR fell to 56% for wheat and 126% for cotton. For a comparison Nagy and Quddus found the IRR for wheat research in Pakistan to be 90% and cotton 80% for a similar time period. We conclude that our estimates are a reasonable approximation of the return on investments made in agricultural research in Turkey

Appendix 1 The Parametric Approach

The parametric approach has a strong theoretical background and uses econometric techniques to measure and decompose the growth of TFP. However, accurate measures of TFP and reliable decomposition of its sources can only be obtained by correctly specifying the appropriate behavioural and structural assumptions of the model. The behavioural assumptions concern the objective function of firms in the industry, the market structure, and the importance of various (economic and environmental) regulations. On the other hand, structural assumptions are related to production structure, i.e. returns to scale, efficiency, capacity utilisation etc. The review of parametric approach is organised on the basis of behavioural assumptions and in particular, on various forms that the objective function of firms may take. We start with TFP measures based on the production function, then look at those based on the cost function and last, the profit function.

Production Function

Consider first the primal framework (i.e., a production function), on which Solow's (1957) seminal work was based. All relationships for measuring and decomposing TFP from estimates of a production function are given in table A2 of appendix A. The first equation refers to the case of long-run equilibrium (for derivation see Hatziprokopiou, Karagiannis and Velentzas, 1996). TFP change is attributed to two factors: returns to scale and technical change. The first term, which refers to the effect economies of scale may have on TFP growth, vanishes under constant returns to scale, and in this case the rate of TFP growth is equal to the (primal) rate of technical change, as in Solow (1957) model. Otherwise, increasing (decreasing) returns to scale may contribute positively (negatively) to TFP growth, even in the absence of technical change, as long as input use increases. The second term is always positive for progressive technical change.

The second relationship refers to the case of long-run equilibrium but in the presence of technical inefficiency (Bauer, 1990). It should be noted that the potential effect of allocative efficiency on TFP cannot be measured within a production function framework; this is one shortcoming of the primal approach. The last two terms in the second relationship presented in table A2 refer to technical change and returns to scale, and their interpretation is as noted above. The first term refers to the changes over time in the degree of technical efficiency. Increases (decreases) in the degree of technical efficiency affect positively (negatively) the growth rate of TFP. Most importantly, improvement of technical efficiency may contribute to TFP growth even in the absence of technical change and economies of scale.

The third formula in table A2 provides a decomposition of TFP change in the presence of temporary disequilibrium; that is, some factor inputs do not adjust optimally to long-run equilibrium conditions and their shadow values differ from their rental prices. In this case, a term accounting for deviations form full capacity utilisation should be incorporated in the relationship used to measure TFP (Bernd and Fuss, 1986). This term (the last term in the third row of table A2) is positive (negative) as shadow prices are greater (less) than market rental prices and capital stock increases. Thus, underutilization (overutilization) of capital stock results in TFP increases as the stock of capital increases (decreases).

Cost Function

The cost function framework offers more options in modelling some behavioural assumptions, such as monopolistic or regulated firms. Furthermore, all structural assumptions can be incorporated in a cost function framework.

First consider the case of a competitive sector in long-run equilibrium with full productive efficiency, developed by Berndt and Khaled (1979). In this case, TFP growth may be decomposed into technical change and returns to scale effects (see the first row of table A3). The rate of technical change is measured by the (dual) rate of cost diminution, corresponding to the first term of this relationship. Given that the rate of cost diminution is negative under progressive technical change, the first terms is positive and thus, technical change positively affects the rate of TFP growth. The second term refers to the scale effect and vanishes under constant returns to scale. Increasing (decreasing) returns to scale may result in TFP growth (slowdown) as long as output increases, with and without technical change. This model has been applied by Capalbo (1988), Glass and

McKillop (1990) and Kuroda (1995) to analyse TFP growth in the agricultural sector of US, Ireland, and Japan, respectively.

The relationship given in the second row of table A3 corresponds to the case of productive inefficiency, developed by Bauer (1990). Given that the rest of behavioural and structural assumptions are as previously, the interpretation of the first two terms is similar as before. The next two terms refer to that portion of TFP growth attributed to improvements in technical and allocative efficiency, respectively. As we have already mentioned, improvements in the degree of technical and allocative efficiency positively affect the rate of TFP growth, and *vice versa*. The last term, called by Bauer "the residual price effect", is due to allocative inefficiency and it is used to correct the measurement of aggregate input, which is based on actual rather than optimal cost shares. If these two are equal to each other, allocative inefficiency is absent and the last terms vanishes.

The third relationship in table A3 incorporates the potential role that environmental regulation may have on TFP growth (Gollop and Roberts, 1983). Given that the corresponding model has built up in a long-run equilibrium framework, our focus is only on the last term, as the first two terms are as described before. This last term indicates the way environmental regulations affect TFP growth. Environmental regulations result in TFP slowdown if their implementation causes an increase in total cost of production, and *vice versa*. Given the existence of significant economies of scope in the production of by-products, which usually cause environmental damages, it is more likely that environmental regulations that limit the production of such products will induce a TFP slowdown.

The next relationship provides a decomposition of TFP growth in the presence of temporary equilibrium (Morrison, 1986, 1992). The last term in the forth row of table A3 corresponds to the market disequilibrium effect. The existence of this term implies that user cost does not reflect the marginal contribution of quasi-fixed inputs into production and their shadow values may be different than their market prices. If shadow values are greater (less) than user cost, the existing stock of quasi-fixed inputs are underutilized (overutilized), implying that capacity utilisation is less (greater) one. Consequently, investment is undertaken in the former case whereas farmers delay their investment plans in the latter. Moreover, the contribution of the disequilibrium effect is positive in the former case and negative in the latter. This model has been used by Mergos and Karagiannis (1997) to explain TFP changes in Greek agriculture.

An extension of the above model can also account for changes in public capital. The corresponding relationship for measuring and decomposing TFP growth is given in the fifth row of table A3. The first three terms have a similar interpretation as before. The last term corresponds to the effect public infrastructure may have on TFP: public infrastructure results in productivity growth as long as the growth rate of public capital stock is less than the growth rate of aggregate output (Morrison and Schwartz, 1994).

The last two rows of table A3 correspond to a decomposition of TFP growth when monopolistic and regulated firms are present, respectively. The last term in the sixth row depicts the effect that monopolistic power has on TFP growth. According to Denny, Fuss and Waverman (1981), this term cannot unambiguously be signed without any further information on monopolist pricing policy and the magnitude of the elasticity of demand. Positive markups for all outputs produced by a monopolistic firms along with a highly elastic demand for each one of them, ensures that this term is positive. On the other hand, regulations concerning the rate of return to capital (the forth term in the last row of table A3) may positively affect TFP growth only when it increases over time. Otherwise, it results in TFP slowdown (Nelson and Wohar, 1983).

Profit Function

Within the profit function framework, two measures of TFP growth may be obtained depending upon the definition of the rate of technical change. As both input and output quantities optimally adjust to price changes when firms maximise profit, the rate of technical change may be determined by holding constant either input or output quantities. These two measures of the rate of technical change are equal to each other under constant returns to scale. Consequently, the two alternative measures of TFP growth are also equal. Nevertheless, both provide similar qualitative information about sources of TFP growth.

The relationships in the first two rows of table A4 refer to the case of long-run equilibrium. The first term in both relations presents the effect of technical change on TFP growth. For a well-defined profit function, this effect vanishes only when the rate of technical change (or equivalently the rate of profit augmentation) is equal to zero. Otherwise, it is expected to be positive. The second term gives the effect of returns to scale. Under decreasing returns to scale, the second term in is negative.

The corresponding relationships for measuring and decomposing TFP growth in the case of temporary equilibrium are presented in the last two rows of table A4. The first term in the third row of table A4 refers to the technical change effect and it is expected to be positive under progressive technological change. The second term refers to the scale effect and it is positive (negative) under short-run increasing (decreasing) returns to scale as long as output increases, and *vice versa*. The last term refers to the temporary equilibrium effect associated with the variable and quasi-fixed inputs, respectively. It is positive (negative) when rental prices are greater (less) than shadow prices, quasi-fixed inputs are over- (under-) utilised and variable inputs use increase. The last term vanishes when shadow and rental prices are equal (Bernstein, 1994; Karagiannis and Mergos, 1997).

The first term in the fourth row of table A4 refers to the effect of technical change on TFP growth, which is expected to be positive under progressive technological change. This corresponds to the output-based measure of the rate of technical change. The second term presents the scale effect since the input-side measure of economies of scale is defined upon both variable and quasi-fixed inputs. Under short-run decreasing (increasing) returns to scale, the second is negative (positive) as long as output increases, and *vice versa*. This term vanishes under short-run constant returns to scale. The third term refers to the temporary equilibrium effect associated with the variable and quasi-fixed inputs, respectively. It is positive (negative) when rental prices are greater (less) than shadow prices, quasi-fixed inputs are over- (under-) utilised and variable inputs use increase. The last terms vanishes when shadow and rental prices are equal. Karagiannis and Mergos (1997) used this model to analyse TFP growth in US agriculture.

Appendix 2 The Non-parametric Approach

The non-parametric approach consists of the most recent methodology to measure TFP growth, but it is still in an infant stage. It is based on mathematical programming techniques and its main advantage is that it does not require any restrictions on the functional specification of the underlying production function. This is a potential not offered by the other two approaches.

In its present state, however, the non-parametric approach enables only measures of TFP growth through the rate of technical change. That is, it only allows one source of TFP growth and this is technical change (Cox and Chavas (1990) and Chavas and Cox (1994)). This consists a serious shortcoming at the present stage, particularly compared with the parametric approach. Further research is required in this direction to augment the prospects of the non-parametric approach.

Nevertheless, there are also significant restrictions in modelling technical change. In the non-parametric approach, technical change is depicted with the so-called augmentation hypothesis. If the augmentation hypothesis is only related to inputs, then technical change can only be specified as Hicks-neutral. If it is related to both inputs and outputs, biased technical change may also be considered. In either case, the augmentation hypothesis is empirically implemented through a scaling or translating form. Both these forms are concerned with the way technical change affect the use of inputs and the production of outputs. By adopting either form to model the augmentation hypothesis, measures of the rate of technical change may be obtained, which are equal to the rate of TFP growth. In any case, this measure of TFP growth consists of the lower limit, i.e., it is a pessimistic estimate.

Another disadvantage of the non-parametric approach is that its computational simplicity decreases significantly as the number of inputs and outputs included in the analysis increases, for any given number of observations. Notice that to measure TFP growth (through the rate of technical change) over a given interval of time, a specific optimisation problem must be solved as many times as the number of periods that are included in the interval.

Table A1: Measuring and Decomposing TFP Growth within a Production Function Framework

1	$(E-1)\sum_{i=1}^{m} s_i \dot{X}_i + T(x;t)$
2	$\dot{T}_p + T(x;t) + \left(1 - \frac{1}{E}\right)\sum_{i=1}^{m} \varepsilon_i \dot{X}_i$
3	$(E-1)\sum_{i=1}^{m} s_i \dot{X}_i + T(x;t) + \sum_{k=1}^{h} \left(\varepsilon_k - s_k\right)\dot{Z}_k$

Note: $E = \Sigma\varepsilon_i = \Sigma\partial \ln f / \partial \ln X_i$ where f(·) is the production function; T(x;t)=$\partial \ln f / \partial t$; T_p is the degree of technical inefficiency; $\varepsilon_\kappa = \partial \ln f / \partial \ln Z_k$ where Z refers to quasi-fixed inputs; and S_i = $\partial \ln f / \partial \ln Xi$ = (w_i/p) (X_i/f) = w_iX_i/TR where TR refers to total revenue.

Table A2: Measuring and Decomposing TFP Growth within a Cost Function Framework

1	$-\varepsilon_{ct} + \left(1-\sum_{j=1}^{n}\varepsilon_j^{CQ}\right)\dot{Q}$
2	$-\varepsilon_{ct} + \left(1-\sum_{j=1}^{n}\varepsilon_j^{CQ}\right)\dot{Q} + \dot{T}_c + \dot{A}_c + \sum_{i=1}^{m}\left(S_i\left(Q,w;t\right) - S_i\right)\dot{w}_i$
3	$-\varepsilon_{ct} + \left(1-\sum_{j=1}^{n}\varepsilon_j^{CQ}\right)\dot{Q} - \sum_{l=1}^{g}\left(\frac{\ln C}{R_l}\right)\left(\frac{dR_l}{dt}\right)$
4	$-\varepsilon_{ct} + \left(1-\sum_{j=1}^{n}\varepsilon_j^{CQ}\right)\dot{Q} + \sum_{k=1}^{h}\varepsilon_k^{CZ}\left(\sum_{j=1}^{n}\eta_j^{k}\dot{Q}_j - \dot{Z}_k\right)$
5	$-\varepsilon_{ct} + \left(1-\sum_{j=1}^{n}\varepsilon_j^{CQ}\right)\dot{Q} + \sum_{k=1}^{h}\varepsilon_k^{CZ}\left(\sum_{j=1}^{n}\eta_j^{k}\dot{Q}_j - \dot{Z}_k\right) + \sum_{s=1}^{f}\left(\frac{r_sK_s}{C}\right)\left(\sum_{j=1}^{n}\eta_j^{ks}\dot{Q}_j - \dot{K}_s\right)$
6	$-\varepsilon_{ct} + \left(1-\sum_{j=1}^{n}\varepsilon_j^{CQ}\right)\dot{Q} + \sum_{j=1}^{n}\left(\frac{p_jQ_j}{\sum_{j=1}^{n}p_jQ_j} - \frac{\varepsilon_j^{CQ}}{\sum_{j=1}^{n}\varepsilon_j^{CQ}}\right)\dot{Q}_j$
7	$-\varepsilon_{ct} + \left(1-\sum_{j=1}^{n}\varepsilon_j^{CQ}\right)\dot{Q} + \sum_{j=1}^{n}\left(\frac{p_jQ_j}{\sum_{j=1}^{n}p_jQ_j} - \frac{\varepsilon_j^{CQ}}{\sum_{j=1}^{n}\varepsilon_j^{CQ}}\right)\dot{Q}_j + \mu\left(\sum_{i=1}^{m}S_i\dot{w}_i + \left(\frac{sK}{C}\right)\dot{s}\right)$

Note: $\varepsilon_{ct} = \partial \ln C/\partial t$; $\varepsilon_j^{CQ} = \partial \ln C/\partial \ln Q_j$; T_C refers to technical efficiency; A_C refers to allocative efficiency; R_l refers to environmental regulations; $\varepsilon_k^{CZ} = \partial \ln C/\partial \ln Z_k; n_j^k = \partial \ln Z_k/\partial \ln Q$; K_s refers to public quasi-fixed inputs; r_s the shadow price of public quasi-fixed inputs; $n_j^{ks} = \partial \ln K_s/\partial \ln Q$; μ is the effective level of regulation; s is the rate of return regulation and K refers to capital.

Table A3: Measuring and Decomposing TFP Growth within a Profit Function Framework

1	$\pi_t\left(\rho^{-1}-1\right)+\left(1-\rho^{-1}\right)\dot{Q}$
	$\pi_t(1-\rho)+(\rho-1)\dot{X}$
2	$\pi_t^s\left(\rho_z^{-1}-1\right)+\left(1-\rho_z^{-1}\right)\dot{Q}+\sum_{i=1}^{n}\left[\frac{(r_k-v_k)z_k}{TC^s}\right]\left(\dot{X}'+\dot{Z}\right)$
	$\pi_t^s(1-\rho_z)+(\rho_z-1)\left(\dot{X}'+\dot{Z}\right)+\sum_{k=1}^{h}\left[\frac{(r_k-v_k)z_k}{TR}\right]\left(\dot{X}'+\dot{Z}\right)$

Note: $\Pi_t = \partial \ln \Pi / \partial t$ where Π is the profit function; ρ_z is a measure of short-term returns to scale; r_k is the rental price of quasi-fixed inputs; v_k is the shadow price of quasi-fixed inputs; TC^s is the shadow cost and $\Pi_t^s = \partial \ln \Pi^s / \partial t$ where Π^s is the restricted profit function.

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