# An Empirical Analysis of TFP Gains in the Agricultural Crop-Sub-Sector of NWFP Using Malmquist Index Approach

Adiqa Kausar Kiani

*Department of Economics, Federal Urdu University of Arts, Science and Technology, Islamabad, Pakistan*

E-mail: adiqakiani@fuuastisb.edu.pk
Tel:92-51-9252853; Fax: 92-51-9252855

## Abstract

This paper investigates the total factor productivity (TFP) performance of NWFP agriculture crop sub-sector from 1970 to 2004. It identifies the sources of growth of TFP growth and assesses TFP growth changes in agriculture crop sub-sector. Data envelopment analysis (DEA) approach is used to estimate the changes in the production frontier. The Malmquist productivity index has decomposed total factor productivity into technological change (TECHCH) and technical efficiency change (EFFCH). TECHCH implies shifts in the frontier or innovation while EFFCH implies catching up to the frontier. Empirical results suggest that the NWFP crop sector features low productivity growth. Catching up is the main driver for TFP growth.

**Keywords:** Malmquist Index, Technological Change, Efficiency Change

## 1. Introduction

The Data Envelopment Analysis (DEA) is a special mathematical linear programming model and test to assess efficiency and productivity. It allows us to estimate changes in total factor productivity and breaking into two main components namely, technological change (TECHCH) and technical efficiency change (EFFCH).

TFP growth measures how much productivity grows or declines over time. When there are more outputs relative to the quantity of given inputs, then TFP has grown or increased. TFP can grow when adopting innovations such as HYV, improved seeds, or which we call “technological change” (TECHCH). TFP can also grow when agriculturists use their existing technology and economic inputs more efficiently; they can produce more with the same inputs for example, labor, capital and technology, or more generally by increases in “technical efficiency” (EFFCH). TFP change from one year to the next is therefore comprised of technological change and changes in technical efficiency.

Due to small size of data sets, DEA method is more appropriate and suitable in this kind of analysis (Chu and Lim 1998). Some other strengths of DEA are demonstrated by the following factors.

- The frontier approach does not require price information;
- It does not assume all firms are fully efficient or it allows inefficient performance;

- It does not need to assume a behavioral objective such as cost minimization or revenue maximization as typical of econometric approach;
- It permits TFP to be decomposed into technological change and technical efficiency change;
- Addition of extra firm in a DEA analysis cannot result in an increase in the TE scores of the existing firms;
- The addition of extra input or output in a DEA model cannot result in an reduction in TE scores (Coelli 1998);
- It can manage multiple inputs and outputs; and
- Measurement error and statistical noise are assumed to be non-existent, thus accurate (Mahadevan 2002).

# 2. The Malmquist Productivity Index (MQI)

The MQI was proposed by Caves *et al*. (1982a, b) based on distance functions developed by Malmquist (1953). Fare *et al*. (1994) decomposed productivity growth into two mutually exclusive components: technological change (TECHCH) and efficiency change (EFFCH) over time. They calculated productivity change as the geometric mean of two Malmquist productivity indexes[1] using output distance functions.

Let the production technology $S^t$ for each time period $t$ = 1, 2, ……,$T$ denotes the transformation of inputs, $x^t \in R^N_+$, in to outputs, $y^t \in R^M_+$,

$$S^t = \{(x^t, y^t) : x^t \text{ can produce } y^t\},$$

Where, $S^t$ is assumed to satisfy the required axioms[2], to define meaningful output distance functions (Fare, 1988). These axioms are necessary to define meaningful output distance functions. Following Shephard (1970) and Fare *et al.* (1994), the output distance function in time period t is defined as[3]:

$$D_0^t(x^t, y^t) = \inf[\theta : (x^t, y^t/\theta) \in S^t] \qquad (1)$$

$$= [\sup\{\ \theta : (x^t, \theta y^t) \in S^t\}]^{-1}.$$

Distance function is defined as the inverse of the maximal proportional increase of the output vector $y^t$, given inputs $x^t$. It is also equivalent to the reciprocal of Farrell’s (1957) measure of output efficiency, which measures TFP: “catching-up” of an observation to the best- practice frontier are defined the degree of productivity (high or low).

---

[1] The conditions include technical efficiency, allocative efficiency, that the underlying technology must be Translog, and that all the second-order terms must be identical over time. In contrast, the Malmquist does not require any assumptions with respect to efficiency or functional form. Our specification of productivity change as the geometric mean of two Malmquist indexes stem from CCD(Caves, Christensen and Diewert).

[2] There are five axioms. Axiom 1: states that the null vector of inputs yields zero output. Axiom 2: says that finite input can not produce infinite output. Axiom 3: states that a proportional increase in inputs does not reduce output (according to Fare et al. (1985), this property is called “weak disposability" of inputs). Axiom 4: is a mathematical requirement to enable the definition of output isoquants as subsets of the boundaries of the output sets. Axiom 5: states that a proportional decrease in outputs remains producible with no change in inputs (following Fare, Grosskopf, Norris & Zhang (1994) this is called “weak disposability" of outputs (Spitzer 1997).

[3] The values of the distance function are the reciprocal of the Farrell’s (1957) measure of the technical efficiency, which calculates “how far” an observation is from the frontier technology.

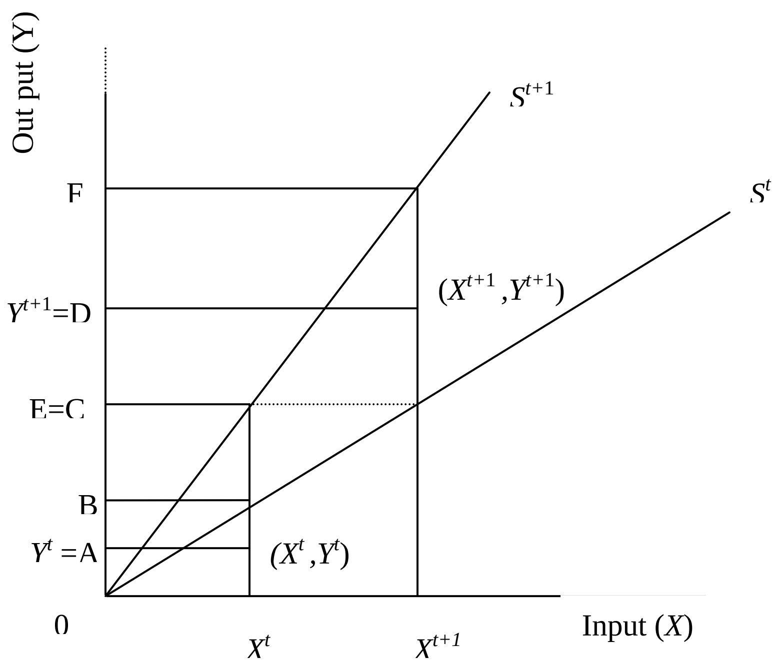
Furthermore, $D_0^t(x^t, y^t) = 1$ if and only if $(x^t, y^t)$ lies on the boundary or frontier of technology $S_F^t$ which occurs only if production is technically efficient. If $D_0^t(x^t, y^t) <$ 1, production at *t* is interior to the frontier of technology at *t*, and $(x^t, y^t)$ is not technically efficient. The distance function measures the degree of technical inefficiency. The output distance function in time period *t*+1, $D_0^t(x^{t+1}, y^{t+1})$, can be defined as in equation (2).

Define output distance functions with respect to two different time periods as:

$$D_0^t(x^{t+1}, y^{t+1}) = \inf[\theta : (x^{t+1}, y^{t+1}/\theta) \in S^t] \qquad \theta > 0 \qquad (2)$$

This is one mixed index that measures the maximal proportional change in outputs $y^{t+1}$ given inputs $x^{t+1}$ under the technology at time period t, which is illustrated in Figure (1). Note that production $(x^{t+1}, y^{t+1})$ lies above the set of feasible production in period t, i.e. technical change has occurred. An intuitive interpretation of the construction of the output distance is given in Figure 1 (Fare et al. (1994)). The distance function value evaluating $(x^{t+1}, y^{t+1})$ related to technology in period t is **OD/OE**, which is greater than one.

***Figure 1: Malmquist Output-Based Index of Total Factor productivity and Output Distance Functions***




Similarly, we defined the mixed distance function, $D_0^{t+1}(x^t, y^t)$, which measures the maximal proportional change in output $y^t$, given inputs $x^t$, with respect to the technology at time period t + 1.

Following Caves et al. (1982a), the Malmquist Productivity Index is defined as:

$$M_0^t = \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \quad . \tag{3}$$

This ratio index measures the productivity changes originating from changes in technical efficiency at time period $t$ and time period $t + 1$ under the technology in time period $t$. the technical efficiency changes from time period $t$ to $t + 1$ can also be measured under the technology in time period $t + 1$. This MQI is defined as:

$$M_1^{t+1} = \frac{D_1^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)}. \tag{4}$$

Fare et al. (1994) specified the out-put based Malmquist productivity change index as the geometric mean of (3) and (4) and decomposed into two parts:

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = [\{ \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \}\{ \frac{D_1^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)} \}]^{1/2} \tag{5}$$

The idea of using the geometric mean of two Malmquist productivity indices is also exploited in the key work of Fare, Grosskopf, Lindgren and Roos (1994). Unlike the Caves, Christensen and Diewert (1982) index where, productive units are assumed to be fully allocative and technical efficient. Feasible Generalized Least Square (FGLR) Malmquist productivity Index allows for the presence of inefficiency. This enables a further decomposition of the productivity growth into technological progress and efficiency change[4]. For the output-oriented case[5], this decomposition is recovered from the expression:

$$= \frac{D_1^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} [\{ \frac{D_0^t(x^{t+1}, y^{t+1})}{D_1^{t+1}(x^{t+1}, y^{t+1})} \}\{ \frac{D_0^t(x^t, y^t)}{D_1^{t+1}(x^t, y^t)} \}]^{1/2}$$

$$= E(x^{t+1}, y^{t+1}, x^t, y^t)\, T(x^{t+1}, y^{t+1}, x^t, y^t). \tag{6}$$

$$E(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_1^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}$$

$$T(x^{t+1}, y^{t+1}, x^t, y^t) = [\{ \frac{D_0^t(x^{t+1}, y^{t+1})}{D_1^{t+1}(x^{t+1}, y^{t+1})} \}\{ \frac{D_0^t(x^t, y^t)}{D_1^{t+1}(x^t, y^t)} \}]^{1/2}$$

$E$ (.) is the relative efficiency change index under the constant returns to scale which measures the degree of catching-up to the best-practice frontier for each observation between time period $t$ and time period $t + 1$, while $T$ (.) represents the technical change

[4] Although Caves, Christensen and Diewert (1982), did not decompose their productivity, it is straight forward to do so. Thus for period t, as Malmquist index $M_0 (x^{t+1}, y^{t+1}, x^t, y^t) = [\{D_0^t (x^{t+1}, y^{t+1}) / D_0^t (x^t, y^t )\}\{ D_1^{t+1} (x^{t+1}, y^{t+1}) / D_0^{t+1}(x^t, y^t )]\}^{1/2}$ , where the first factor in brackets measures the technical change using period t + 1 data and second is the technical change component calculated under a variable return to scale reference technology.

[5] Under some productive frameworks where output is given, the idea of measuring efficiency and productivity change on the grounds of maximum proportional reductions in all inputs given an available technology by means of input distance function rather than output ones may provide important insights. This reasoning led to the literature on the computation of Malmquist input based measures of productivity change such as those utilized in Fare, Grosskopf, Lindgren and Roos (1992), Fukuyama and Weber (1999).

index which measures the shift in the frontier technology (or innovation) between two time periods evaluated at $x^t$ and $x^{t+1.}$

Malmquist Index of total factor productivity change (TFPCH) is the product of technical efficiency change (EFFCH) and technological change (TECHCH) as expressed (Cabanda, 2001):

$$TFPCH = EFFCH \times TECHCH \qquad (7)$$

The decomposition of the MQI allows us to identify the contribution of catching-up in efficiency and innovation in technology to the TFP growth. According to Fare *et al*. (1994), MQI greater than one indicate growth in productivity. MQI less than one indicate decline in productivity. In addition, improvement in any of two components of MQI is also associated with the value greater than one, and declines are associated with values less than one. The Malmquist productivity index can be re-written in terms of distances along y-axis using the notation in Figure (5.1) as:

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = \left(\frac{OD}{OF}\right)\left(\frac{OB}{OA}\right)\left[\left(\frac{OD/OE}{OD/OF}\right)\left(\frac{OA/OB}{OA/OC}\right)\right]^{\frac{1}{2}} \qquad (8)$$

$$= \left(\frac{OD}{OF}\right)\left(\frac{OB}{OE}\right)\left[\left(\frac{OF}{OE}\right)\left(\frac{OC}{OB}\right)\right]^{\frac{1}{2}}$$

The Malmquist index can be calculated in several ways[6]. As mentioned earlier, the term outside brackets show change in relative efficiency at *t* and *t* +1, i.e. whether production is catching up or far from the frontier. The ratios in the brackets capture shifts in technology at input levels $x^t$ and $x^{t+1,}$ respectively. Thus the technical change is equal to the geometric mean of these two shifts.

If the Malmquist productivity index is greater than one, the improvement in productivity is achieved; if the Malmquist productivity index is less than one, the productivity deteriorates; and if the Malmquist productivity index is equal to one then no change occurred in productivity. Similarly, the deterioration in any of the components of the Malmquist index is associated with the values less than one of these components, and improvements are associated with values greater than unity. It is important to note that product of efficiency change and technical change components may be moving in opposite direction.

For example, let an efficiency change component be greater than one (e.g. 1.8) and a technical- change component less than one (e.g.0.7) then a Malmquist index will be 1.26 which is greater than one (i.e. it shows productivity gain).

We have also used the same model as given in equation (5.24), in our study for efficiency analysis by applying Malmquist index technique, which shows that TFP change is the product of efficiency change and technological change.

---

[6] Nishimizu & Page(1982) proposed a decomposition using a stochastic production frontier approach.
Kalirajan & Obwona (1994) were using the varying coefficients production frontier approach to decompose total factor productivity. Both approaches need information about data on prices and require specifications of the underlying functional form of technology. The approach chosen in this paper needs neither of these requirements.

## 3. Methodology
## 3.1. Malmquist Productivity Index Estimates

Since Malmquist productivity index is an index based on discrete time, each province will have an index for every pair of years. This entails calculating the component distance functions using linear programming methods. Recall that if the value of Malmquist index or any of its components is less than one, it denotes regress or deterioration in performance, whereas values greater than one denote improvement in relevant performance. Also recall that these measures capture performance relative to the best practice in the sample, where practice represents “regional frontier”.
Estimates of Malmquist index and its component regarding the crops sub-sector of Punjab are presented in Table 1. On average, technological change showed a value greater than one[7] indicating that the technological change has occurred in crops sub-sector of Punjab. However, due to prevalence of large inefficiency in this sector overall total factor productivity does not show any improvement overtime. Reasons for prevalence of these inefficiencies in the agriculture sector may include massive government policy interventions, wide spread illiteracy among farmer, and poor infrastructure and agricultural support services etc.

Turning to the year-to-year results, the decade of 1990s can be termed as the decade of technological change as the TECHCH is grater than one during most of the years in this decade. However, the value of TFPCH was the lowest during 1993 (Table 1). In fact, the year 1992-93 was extremely abnormal year for agriculture on account of several exogenous factors. Unprecedented floods hit the main crop growing areas in Punjab; major brunt was born by kharif crops. The cotton crop was biggest victim as the losses by flood were further aggravated by spread of cotton leaf curl virus.

In the year 1995, the value of TFPCH is highest; during 1994-95 this sector has shown remarkable improvement in its growth as compared to previous years. It has recorded a sharp revival in the growth of major crops, redeemable feature of major crops sub sector is that declining trend in cotton has not only been stemmed but also has been attained high production.

In 1970s, little technological change occurred in Punjab as the value of TECHCH throughout this decade remained less than one except for a couple of years. The decade of 1980s showed mixed trend in TECHCH. Although the average results with respect to technical change are suggestive, they do not allow us to identify which years are shifting the frontier over time. The technical change component of the Malmquist index tells us what happened to the frontier at the input level and mix of each year, but not whether that year actually caused the frontier to shift. In order to provide evidence as to which province were “innovators” we need to see the component distance functions in the technical change index, specifically if,

[7] Subtracting 1 from the number reported in table gives average increase or decrease per annum for the relevant time period and the relevant performance measure.

$$TC^k > 1$$

$$D_0^t(x^{k,t+1}, y^{k,t+1}) > 1$$

$$D_o^{k,t+1}(x^{k,t+1}, y^{k,t+1}) = 1$$

$$where\ k = 1,2,...K\ provinces$$

Then the province has contributed to shift in the frontier between t and t + 1. Since the Punjab also determined the frontier in each year under constant returns to scale, it is classified as the sole innovator given those technologies. (See Table 2)

## NWFP

The Malmquist indices for crops sector of NWFP province are reported in Table 1. The TFPCH ranges from the lowest value of 0.241 during 1972 to the highest value of 1.426 during 1997. However, the average annual value of TFPCH for the entire period is smaller than one and reveals that there has been deterioration in technological progress in the crops sub-sector of NWFP. There has been no upward shift in the frontier as the value of TECHCH is less than one. TFPCH decline was due to unfavorable changes in efficiency as well as technology.

***Table 1: Malmquist Index Summary for NWFP***

| Years | EFFCH | TECHCH | TFPCH |
|---|---|---|---|
| 1970 | 0.879 | 1.474 | 1.296 |
| 1971 | 0.857 | 1.397 | 1.197 |
| 1972 | 0.679 | 0.315 | →0.214 |
| 1973 | 0.978 | 0.385 | 0.377 |
| 1974 | 0.879 | 0.809 | 0.711 |
| 1975 | 0.879 | 0.948 | 0.833 |
| 1976 | 0.896 | 0.503 | 0.451 |
| 1977 | 0.978 | 0.988 | 0.966 |
| 1978 | 0.879 | 0.963 | 0.846 |
| 1979 | 0.867 | 0.699 | 0.606 |
| 1980 | 0.967 | 0.733 | 0.709 |
| 1981 | 0.857 | 1.075 | 0.921 |
| 1982 | 0.897 | 0.885 | 0.794 |
| 1983 | 0.978 | 0.754 | 0.737 |
| 1984 | 0.698 | 1.422 | 0.993 |
| 1985 | 0.987 | 1.073 | 1.059 |
| 1986 | 0.879 | 0.684 | 0.601 |
| 1987 | 0.899 | 0.862 | 0.775 |
| 1988 | 0.987 | 0.864 | 0.853 |
| 1989 | 0.987 | 1.033 | 1.020 |
| 1990 | 0.879 | 0.736 | 0.647 |

| | | | |
|---|---|---|---|
| 1991 | 0.879 | 1.016 | 0.893 |
| 1992 | 0.979 | 0.763 | 0.747 |
| 1993 | 0.733 | 1.357 | 0.995 |
| 1994 | 0.769 | 0.852 | 0.655 |
| 1995 | 0.998 | 1.284 | 1.281 |
| 1996 | 0.876 | 0.959 | 0.840 |
| 1997 | 0.768 | 1.857 | →1.426 |
| 1998 | 0.487 | 1.950 | 0.950 |
| 1999 | 0.879 | 0.492 | 0.432 |
| 2000 | 0.898 | 0.738 | 0.663 |
| 2001 | 0.877 | 0.694 | 0.609 |
| 2002 | 0.867 | 0.945 | 0.819 |
| 2003 | 0.844 | 1.126 | 0.950 |
| 2004 | 0.899 | 0.749 | 0.673 |
| **Geometric Mean** | **0.865** | **0.889** | **0.769** |

During 1996-97, highest value of total factor productivity change showed that there was increase in production of major crops due to price incentives, early receipt of monsoon rains in the rice zone and adequate water supply during transplantation period coupled with less attacks of pest/insect and disease, more application of fertilizers to the crop and other agronomical practices.

There has been an improvement in the efficiency scores of NWFP crop sector relative to previous years, with 1.08 percent in period (t+1), compared to -2.44 percent in period t, with a growth changes of -1.42 percent growth.

***Table 2: Distance Summary of NWFP***

| ***Year*** | ***t*** | ***t + 1*** |
|---|---|---|
| 1970 | 2.782 | 1.437 |
| 1971 | 2.805 | 2.104 |
| 1972 | 11.279 | 9.200 |
| 1973 | 1.364 | 2.635 |
| 1974 | 1.587 | 1.949 |
| 1975 | 1.751 | 5.011 |
| 1976 | 1.268 | 1.949 |
| 1977 | 1.887 | 2.203 |
| 1978 | 2.038 | 3.090 |
| 1979 | 1.518 | 2.079 |
| 1980 | 1.149 | 1.383 |
| 1981 | 1.577 | 1.847 |
| 1982 | 1.464 | 2.212 |
| 1983 | 1.259 | 1.052 |
| 1984 | 2.128 | 1.252 |
| 1985 | 1.442 | 2.320 |
| 1986 | 1.099 | 2.139 |
| 1987 | 1.562 | 1.911 |
| 1988 | 1.421 | 1.154 |
| 1989 | 5.738 | 2.426 |
| 1990 | 1.352 | 1.839 |

| | | |
|---|---|---|
| 1991 | 1.886 | 2.182 |
| 1992 | 1.250 | 1.287 |
| 1993 | 2.573 | 1.823 |
| 1994 | 1.194 | 1.202 |
| 1995 | 2.154 | 1.547 |
| 1996 | 1.456 | 1.415 |
| 1997 | 4.879 | 2.534 |
| 1998 | 9.500 | 9.522 |
| 1999 | 2.360 | 1.976 |
| 2000 | 1.050 | 2.343 |
| 2001 | 1.137 | 1.482 |
| 2002 | 1.276 | 1.401 |
| 2003 | 1.769 | 2.092 |
| 2004 | 1.172 | Not Included |
| **Average Compound Growth Rate** | **-2. 44 %** | **1. 079 %** |

$$\text{TFP Growth Change (NWFP)} = \frac{[1.079 - (-2.44)]}{(-2.44)}$$

$$= -1.42\ \%$$

***Figure 2: Decade Average Distance Summary of NWFP***

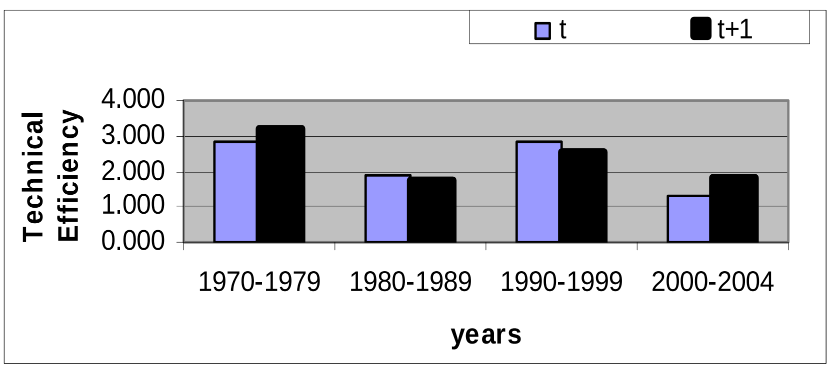
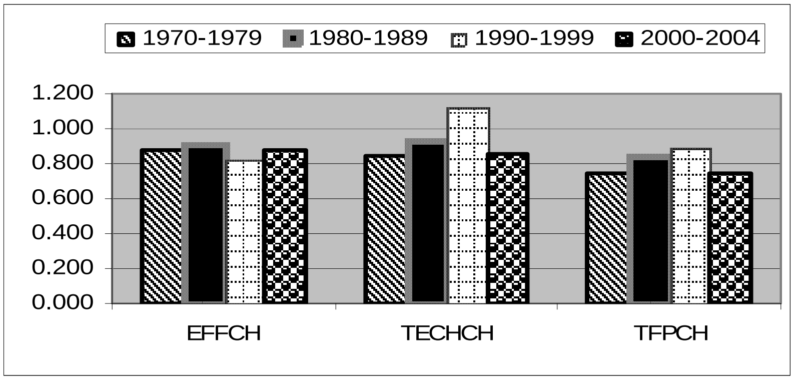


**Figure 3: Decade Average Efficiency and Productivity Change (NWFP)**




## Conclusion

The efficiency results obtained by DEA yield value of inputs and outputs that NWFP would be able to achieve. However, some factors that influence performance may not be under the control of NWFP Province concerned. DEA-Malmquist is limited only to input and output variables used to construct the model to estimate the changes or total factor productivity and to identify the sources of this TFP growth that will help in policy formulation for an industry.

## References

[1] Caves, D.W., L. R. Christensen, and W.E. Diewert (1982), "Multilateral Comparison of Output, Input, and Productivity Using Superlative Index Numbers", *The Economic Journal*, 92, Pp. 73-86.

[2] Coelli, T.J., D.S. Prasada Rao and G.E. Battese (1998), "*An Introduction to Efficiency and Productivity Analysis*" Kluwer Academic Publishers, Boston.

[3] Coelli, Tim. (1996)," A Guide to DEAP Version 2.1: A Data Envelopment Analysis Computer Program", Armidale, NSW, Australia, Department of Econometrics, and University of New England.

[4] Coelli, Tim. (1998), "Productivity in Australian Electricity Generation: With the Real TFP Measure Please Stand Up". CEPA Working Paper. Department of Econometrics and University of New England.

[5] Coelli, Tim and Parasada Rao (2003), "Total Factor Productivity Growth in Agriculture: A Malmquist Index Analysis of 93 countries 1980-2000", International Association of Agricultural Economics, Durban

[6] Fajnzlber, P. and D. Lederman (1999)**,** "Economic Reforms and Total Factor Productivity Growth in the Latin America and the Caribbean, 1950-95: An Empirical Note", World Bank, Policy Research Working Paper Series, No.2114.

[7] Fare, R. & Grosskopf, S. (1992), "Malmquist productivity indexes and Fisher Ideal indexes", *The Economic Journal*, 102, Pp.158-160.

[8] Fare, R., Grosskopf, M. Norris and Z. Zhang (1994), “Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries”, *American Economic Review*, 84, Pp. 66-82.

[9] Fare, R., S. Grosskopf, B. Lindgren, and P. Roos (1994), “*Productivity Development in Swedish Hospitals: A Malmquist Output Index Approach*”, Kluwer Academic Publisher, Boston.

[10] Farrell, M.J.(1957), “The Measurement of Productive Efficiency”, Journal of Royal Statistical Society, 120, Pp. 253-282.

**[11]** Fukuyama, H, and W.L. Weber (1999), “The Efficiency and Productivity of Japanese Securities Firms: 1988-1993, *Japan and World Economy*, 11(1), Pp. 115-133.

[12] Frisvold, G. and K. Ingram (1995), “Sources of Agricultural Productivity Growth and Stagnation in Sub-Saharan Africa”, *Agricultural Economics*, 13: Pp. 51-61.

[13] Kalirajan, K. & Obwona, M. (1994), “Frontier Production Function: The Stochastic Coefficients Approach”, Oxford Bulletin of Economics and Statistics 56, Pp. 85-94.

[14] Mahadevan, Renuka, (2002), “Is There a Real GDP Growth Measure for Malaysia’s Manufacturing Industries?” ASEAN Economic Bulletin 19, 2. Pp 178-190.

[15] Malmquist, S. (1989), “Index Numbers and Indifference Curves”, *Econometrica*, 4, Pp. 209-242.

[16] Nishimizu, M. & Page, J. (1982), “Total Factor Productivity Growth, Technological Progress, and Technical Changes: Dimensions of Productivity Change in Yugoslavia, 1965-1978”, *Economic Journal*, 92, Pp. 921-936.

[17] Spitzer M. (1997), “Interregional Comparison of Agricultural Productivity Growth, Technical Progress, and Efficiency Change in China’s Agriculture: A Non- Parametric Index Approach”, Interim Report, International Institute for Applied System Analysis (IIASA), Laxenburg, Austria.