Global Journal of Science Frontier Research
Agriculture and Veterinary
Volume 13 Issue 10 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Overtime Growth in Crop and Livestock Productivity in Pakistan's Provincial Context

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GJSFR-D Classification : *FOR Code: 620501p, 860703*

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I. Introduction

The agricultural sector in Pakistan comprises both crop and livestock industries in its four provinces, namely Punjab, Sindh, Khyber Pakhtunkhwa (KP) and Balochistan. Growth in Total Factor Productivity (TFP) in both sets of sectors is a vital consideration for planners and policy makers (Govt. of Pakistan, 2009, 2010d and 2011). In the post-independence era, a pragmatic approach for development of Pakistan's crop sector initiated in 1960s with the in-coming of green revolution technologies. Later in 1980s, several dimensions added to the Pakistan's agrarian economy, such as mechanical cultivation replaced bullock farming, arable land per capita was reduced and the livestock industries emerged as a major source of livelihood. It is noteworthy that the contribution of livestock to agriculture's value added in GDP increased from 28% in 1980-81 to 53% in 2009-10 (Govt. of Pakistan, 1981 and 2010c).

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Ellahi, *et al.* (2010 and 2012) conducted two separate studies on TFP for crops (1980-81 to 2005-06) and livestock (1980-81 to 2008-09), from where it transpired that TFP for the former was much higher than the latter. Although both industries are subject to vagaries of nature, but growth in livestock industries is observed to be relatively more stable, impressive and sustainable as compared with crops (Govt. of Pakistan, 2010c). However, there are evidences (Ellahi, *et al.*, 2010 and 2012) that the varying resource endowments across the country lead to uneven distribution in growth of crop-livestock combined TFP across the four provinces. This requires that estimates of combined TFP be carried out to assist the planning machinery for undertaking an integrated development plan for the overall agricultural sector. Further, crop and livestock enterprises are complementary to each other as fodders and crop byproducts, such as straw from wheat, rice and gram and sugarcane tops are used as feed for livestock. Therefore, the participation of spatial entities in this growth process needs to be ascertained and tested in the light of empirical results and other factors operating in the overall economy.

Most spatio-temporal studies of TFP growth in Pakistan related to crops. Examples are Ellahi (2007), Ellahi, *et al.* (2009, 2009a and 2010), Ali (2000 and 2005), Murgai, *et al.* (2001), Khan (1994 and 1997), Ali and Velasco (1994), Rosegrant and Evenson (1993), Azam, *et al.* (1991) and Wizarat (1981). A similar study was carried out by Ellahi, *et al.* (2012) for the fast-growing livestock sector.

II. Materials and Methods

a) Method of Analysis

Several methods have been used to measure TFP in Pakistan. They include non-parametric linear programming (Ellahi, 2007; Ellahi *et al.,* 2009a, 2009b; Wizarat, 1981), index number methods (Azam *et al.*, 1991, Ellahi, 2007, Ellahi *et al.,* 2009a, 2009b, 2010 and 2012, Rosegrant and Evenson, 1993; Khan, 1997; Ho and Arif, 2004; Ellahi, 2007), and stochastic frontier analysis (Ahmad, 2003). The consideration of crops and livestock and time periods covered in various studies are different, ranging from 1953-54 to 1978-79 for Pakistan agriculture as a whole (Azam *et al.*, 1991), the period 1956-85 for the crop sectors in Pakistan and India (Rosegrant and Evenson, 1993), the period from 1960 to 1996 (Khan, 1997), from 1980-81 to 2005-06

(Ellahi, 2007; Ellahi *et al.,* 2009a, 2009b and 2010) and 1980-81 to 2008-09 (Ellahi, 2012). Ali and Byerlee (2002) used data on 33 crops and eight livestock products in all irrigated districts of Punjab. Ellahi *et al.* (2010 and 2012) considered 17 crop and 11 livestock products, respectively.

The spatio-temporal combined TFP analysis of crop and livestock production in Pakistan is proposed to be carried out for 30 years from 1980-81 to 2009-10. A two-stage analysis of the combined TFP change at the provincial level is undertaken using aggregate data for the four provinces. In the first stage, changes in TFP indices are to be measured, which is accomplished by using annual data on quantities and prices of crop and livestock inputs and outputs. In the second stage, following Rosegrant and Evenson (1993), the combined TFP index is regressed on determinants using a pooled model for all four provinces. Intercept dummies and spatial interaction variables are proposed to be included for Sindh, KP and Balochistan, with Punjab treated as the base.

Obtaining data on the determinants of TFP change proved to be challenging and some of the variables are proxies. The quantity of water, in million acre feet (MAF), obtained from tubewell and canal sources may capture the effects of hydrological developments on crop and fodder production and growth of grasses in the grazing lands. Road density (road length per thousand of rural population) is used to capture the effects of transport infrastructure for marketing of crop and livestock products. Research and extension (R&E) inputs, separately for crop and livestock, are measured from data on provincial expenditure in these services, to capture the effects of increased crop output, improved feeds, disease control and better animal health. The number of tractors per cultivated hectare may depict the level of mechanical technology as a replacement for bullocks in each province. The literacy rate, nutritional status and medical facilities represent human capital. Finally, product of the proportion of cases disposed of in the High Court and Supreme Court represents confidence of farmers in protection of the legitimate rights.

b) Index Method

The chain-linked Törnqvist TFP index (Törnqvist, 1936 in Coelli *et al.*, 2005) was selected to measure TFP change in livestock industries. This method was used in most previous studies of TFP growth and requires the aggregation of inputs and outputs into single indices using weights based on cost and revenue shares, respectively. In order to define the Törnqvist index, the input-output quantities and their respective shares in the total cost and total revenue, respectively, need to be defined. The rationale for selection of the Törnqvist TFP index is provided by Ellahi *et al.* (2010).

Coelli *et al.* (2005) defined the Törnqvist output quantity index in multiplicative form as:

$$Q_{st}^{T} = \prod_{m=1}^{M}\left[\frac{q_{mt}}{q_{ms}}\right]^{\frac{\omega_{ms}+\omega_{mt}}{2}} \quad (1)$$

where q_{ms} is the m-th output quantity in the base period, s, q_{mt} is the m-th output quantity in the current period t, and ω_{ms} and ω_{mt} are the revenue shares of output m in periods s and t, respectively. Following a similar procedure, Coelli et *al.* (2005) defined the Törnqvist input quantity index in its multiplicative form as:

$$\prod_{n=1}^{N}\left[\frac{x_{nt}}{x_{ns}}\right]^{(\omega_{nt}+\omega_{ns})/2} \quad (2)$$

where x_{ns} is the n-th input quantity in the base period, s, x_{nt} is the n-th input quantity in the current period, t, and ω_{ns} and ω_{nt} are the cost shares of input n in periods s and t, respectively. The average annual change in the Törnqvist TFP index was measured using these output and input quantity indices and following the standard procedure as detailed, for example, by Murgai *et al.* (2001).

c) Data Compilation

As mentioned above, the requisite data for crops and fruits were collected by Ellahi (2007) and Ellahi *et al.* (2010) for 26 years (1980-81 to 2005-06). These data were extended for another 4 years, i.e. up to 2009-10 and some other crops, such as sorghum, millet, barley and green fodders were included, while on the input side bullock draught power was added to data on fertilizer, irrigation, plant protection and labour used in Ellahi *et al.* (2010). The data series on livestock (Ellahi *et al.*, 2012) were extended accordingly so that analysis of the combined TFP may be undertaken consistently for the study period considered in this study.

Aggregate data for crops and livestock were collected on prices and quantities of crops (wheat, rice (coarse and fine), sugarcane, cotton, maize, sorghum, millets, barley, fodders, potato, onions, gram, pulses, special oilseeds, sugar beet, tobacco, almonds, apricots, bananas, citrus, dates, guava and mango), milk, draught power, beef, mutton, poultry meat, eggs, hides, skins and wool, and on the inputs used in the production of crop and livestock outputs. Annual input-output data and those for market prices for both crop and livestock at the country level are available in the *Economic Survey* (Govt. of Pakistan, 2010c), the *Agriculture Statistics of Pakistan* (Govt. of Pakistan, 2010a), the *Pakistan Statistical Year Book* (Govt. of Pakistan, 2010h) and the *Monthly Statistical Bulletin* (Govt. of Pakistan, 2010g). The marketing of sugarcane, sugar beet and special oilseeds is institutionally carried out by the sugar industry and Ghee Corporation,

respectively. Therefore, market prices are not available and support/indicative prices announced by the government were used. The support prices for sugar beet and special oilseeds were discontinued in 1990-91 and 1999-2000, respectively. The former is exclusively grown in KP and extension in its prices was based on those for sugarcane and the same for the latter were extended on the basis of past trend.

The national data on livestock were apportioned into provinces using the ratios of different types of stock obtained from data provided in the *Livestock Censuses of 1976, 1986, 1996 and 2006* (Govt. of Pakistan, 1978, 1988, 1998 and 2008). Data on inputs include milk for off-springs, green fodders, crop byproducts, concentrates, manufactured feeds, grains and a variety of feeds for poultry, animal health care, medical treatment and human labour used for livestock activities. Several crop byproducts are used for feed in livestock industries, i.e. straw from wheat, rice and gram, stalks from maize, millets and sorghum and tops from sugarcane. Their annual values in current prices are provided in the *Agriculture Statistics of Pakistan* (Govt. of Pakistan, 2010a) for country as a whole. The provincial apportionment was undertaken in accordance with spatial share in total value of the main output.

The basic sources of data on the agricultural labour are the *Population Censuses of Pakistan 1981 and 1998* (Govt. of Pakistan, 1984 and 2002) and the annual series of the *Labour Force Surveys* (Govt. of Pakistan, 2010f). These data, published in the *Economic Survey* (Govt. of Pakistan, 2010c), are for the country as a whole and relate to crops and livestock. Annual farm wages for casual labour used in the agriculture sector and wages for unskilled labour in the metropolitan areas are available in the *Monthly Statistical Bulletin* (Govt. of Pakistan, 2010g) and in the *Economic Survey* (Govt. of Pakistan, 2010c), respectively. Various issues regarding farm labour and wages thereof, for the period 1980-81 to 2005-06, are discussed by Ellahi (2007), whose method was followed to obtain and extend labour used for crops and livestock and wages thereof up to 2009-10.

For the econometric analysis, data on road density are obtainable from the Provincial *Development Statistics* (Govts. of Punjab, Sindh, KP and Balochistan, 2010c). Data on population and literacy for the years 1981 and 1998 are available in the *Population Censuses of Pakistan 1981 and 1998* (Govt. of Pakistan, 1984, 2002), while those for the remaining study years are obtained from the *Labour Force Surveys* (Govt. of Pakistan, 2010f). Data on irrigation, obtained from the *Agriculture Statistics of Pakistan* (Govt. of Pakistan, 2010a), is comprised of water volume in MAF delivered by the canals and tubewells separately.

Expenditures on R&E for crops and livestock are comprised of development and recurring accounts incurred by the provincial and federal governments. Each provincial government makes expenditure on R&E from the development account until an activity is completed and thereafter the recurring expenditure is sanctioned. At the federal level, the pattern and type of budget allocation is same and its main organizations are the former Food & Agriculture and Livestock Divisions and Pakistan Agricultural Research Council. The latter has components for both crops and livestock. The collection of all these data is a gigantic task. On the provincial side, these data are consistently available in Govt. of Punjab (2010a and 2010b), while these are partially so for Govt. of Sindh (2010a and 2010b), Govt. of KP (2010a, 2010b and 2010d) Govt. of Balochistan (2010a and 2010b) and Govt. of Pakistan (1992). Data for Sindh, KP and Balochistan were estimated in two steps, i.e. the ratio of their partially available information with those for Punjab was obtained first. Then, for the deficient years, a product of the said ratio and data for Punjab were used to estimate those for the remaining provinces.

Annual R & E data for crops and livestock are inconsistently published for the study period by Govt. of Pakistan (2010b). For instance, crop and livestock data (considered for the extension component) were available for the years up to 1997-98; thereafter, they were combined with the overall agricultural R&E data. Data for years after 1997-98 were obtained by using the proportionate share of crops and livestock, in value added, in total agricultural R&E in 1997-98. Data on research expenditure are available for the whole of agriculture. The crop and livestock portions were obtained using the method applied for the extension component. Ultimately, the federal data were apportioned among the four provinces in the light of their respective shares in the total R&E budgets and added to their respective accounts to construct the overall R&E variables for crops and livestock. Thereafter, the estimates were converted into real values by using the GDP deflator with 1980-81 as the base (Govt. of Pakistan, 2010c). Variables on treatment reflecting animal health were taken from the Govts. of Punjab, Sindh, KP and Balochistan (2010c).

A moving average of the crop and livestock output variables need to be used to reduce the exaggerated effects of drought, floods and good seasons on crop output and for ample fodders and free of epidemics. These factors do not operate at a regular interval. However, a period of two years was considered appropriate to smooth out fluctuations in the combined TFP.

III. Results and Efiscussion

a) Estimates of TFP Change

The empirical results of average annual growth rates in combined TFP using Törnqvist indices are presented in Table I for the whole study period and for two sub-periods, namely 1980-81 to 1994-95 and 1995-

96 to 2009-10. Indices are also depicted graphically for Punjab, Sindh and KP in Fig. 1 and for Balochistan in Fig. 2. The trend in combined TFP for Balochistan is portrayed separately because its production pattern, especially that of crops (Ellahi *et al.* 2010), was substantially different from rest of provinces over the study period. As seen from Table I, Balochistan's combined TFP change per annum, for the entire study period, is about four times higher than that for the rest all provinces exhibiting about 1% average annual change.

Table I : Province-wise annual rates of change in TFP

Province Period	Punjab % p.a.	Sindh % p.a.	KP % p.a.	Balochistan % p.a.
1980-81 to 2009-10	0.83	1.05	1.27	4.01
1980-81 to 1994-95	0.87	0.64	1.66	7.25
1995-96 to 2009-10	0.41	0.94	-0.25	-2.67

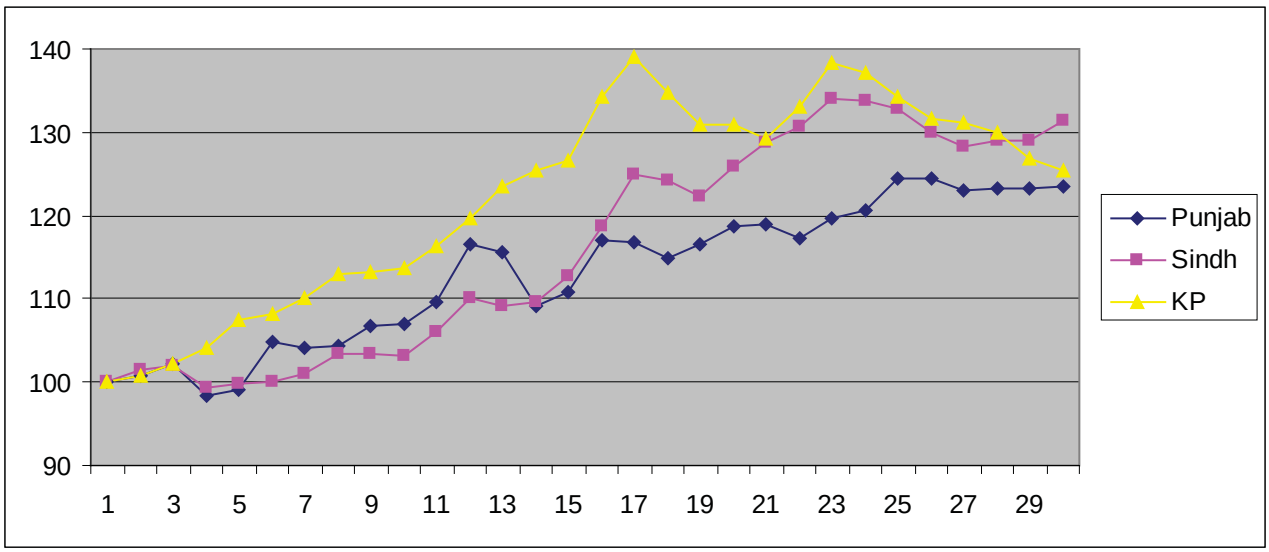

Figure 1 : Annual TFP Indices in Punjab, Sindh and KP, 1980-81 – 2009-10 (1980-81 = 100) for Crop-Livestock Industries Combined

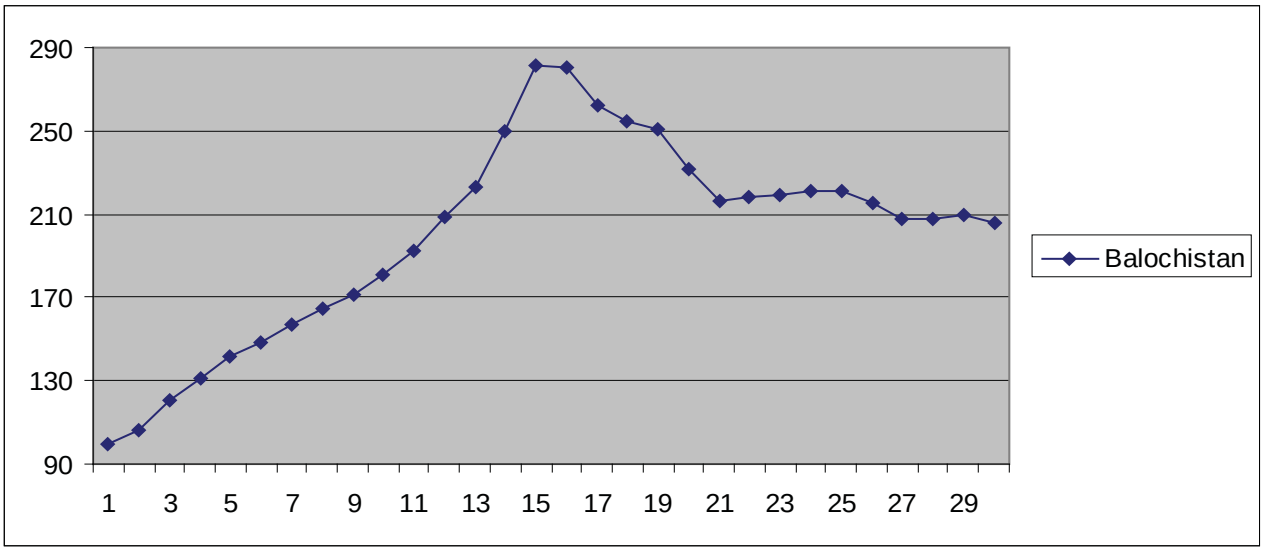

Figure 2 : Annual TFP Indices in Balochistan, 1980-81 – 2009-10 (1980-81 = 100) for Crop-Livestock Industries Combined

The results depicted in Figure I exhibit that the growth rate in the combined TFP for the entire study period and for Punjab, Sindh and KP was almost the same and stood at about 1% per annum. These estimates are lower than those for crop production (Ellahi *et al*., 2010, Ali and Byerlee, 2004 and World Bank, 2007) and higher than those for livestock (Ellahi *et al*., 2010). Further, KP scored the highest with an estimated 1.27% growth in the combined TFP per annum implying that crop and livestock activities, taken together, in KP is more efficient than that in Punjab and Sindh. The producers in Balochistan achieved the highest combined TFP growth rate of 4.01% per annum for the entire study period, but was well below producers in other provinces in the beginning of the study period. This phenomenon is attributed to additional canal water provided to Balochistan in the beginning of 1990s (Abbasi *et al*., 2012), which gave a boost to crop output (Ellahi, 2007).

These average annual TFP growth rates for the whole study period hide some major inter-temporal variations. During the first sub-period from 1980-81 to 1994-95, the combined TFP growth rate was consistently high in all provinces, except Sindh (Fig. 1). It was especially high in Balochistan where farmers achieved high productivity gains of 7.25% per annum. But the rate took a downturn in that province in the second time period (1995-96 to 2009-10), i.e. it retarded at an average annual rate -2.67% per annum (Fig. 2). A slight downturn of -0.25% per annum was recorded in KP as well. The combined TFP growth, in Punjab, dropped from 0.87% to 0.41% per annum compound, i.e. about one half, while the same in Sindh went up annually from 0.64% to 0.94% on an average. In the second time period, Sindh showed the highest TFP growth rate at 0.94%. The drop in the combined TFP growth rate in Punjab, KP and Balochistan in the second time period coincided with a reduction in beef and mutton production (Ellahi *et al*., 2012).

b) Changes in the Determinants of TFP

The rates of change in the determinants of combined TFP, along with *t*-ratios, are provided in Table II. All provinces experienced significantly positive trends in their tubewell networks: the growth was somewhat weak in KP. Its growth was higher in Punjab and Balochistan than in Sindh and KP. It is noteworthy, in Sindh, that water is not mined from below the ground where it is brackish; rather, it is generally canal water that has to be lifted mechanically. Sindh and KP experienced a substantial decline in the canal network, while it showed increasing trend in Punjab and Balochistan. As said above, tubewells in Sindh draw water from canal and lead to reduction in surface water supply.

Table II : Rates of change in determinants of combined TFP in provinces

Variables	Punjab % p.a.	Sindh % p.a.	KP % p.a.	Balochistan % p.a.
Tubewell network	2.093 (19.2)***	1.636 (7.4) ***	0.153 (1.0)	2.171 (11.0)***
Canal network	1.455 (37.4)***	-0.136 (-1.4) ***	-0.962 (-11.3)***	2.326 (15.9)***
Road network	3.691 (22.6)***	-1.043 (-2.6) **	1.2 (17.9)***	-2.204 (8.7)***
Nutritional status	1.385 (14.2)***	0.964 (10.0) ***	5.201 (23.5)***	2.333 (13.2)***
Literacy rate	6.490 (16.5)***	3.977 (25.7) ***	5.269 (22.568)***	7.785 (17.3)***
Medical services	1.068 (10.6)***	-1.845 (-9.2) ***	0.239 (4.4)***	1.482 (8.8)***
Legal services	1.838 (4.1)***	0.246 (0.5)	0.639 (0.9)	2.478 (2.7)***
Extension services (Livestock)	-2.930 (-8.4)***	-3.201 (-7.3) ***	-8.632 (-21.7)***	-0.081 (-0.1)
Research services (Livestock)	2.153 (4.8)***	-1.789 (-2.2) **	3.959 (10.3)***	-0.758 (-1.8)*
Extension services (Crops)	-2.765 (-5.5)***	-4.319 (-4.8) ***	-0.148 (-0.2)	-2.662 (-6.9)
Research services (Crops)	1.627 (3.5)***	-1.161 (-3.3) ***	-1.563 (-3.2)***	-0.701 (-3.5)***

Mechanization	1.405 (4.9)***	-0.158 (-0.4)	0.101 (0.4)	1.589 (5.2)***
Animal health	0.837 (8.0)***	6.748 (11.9) ***	3.475 (13.5)***	0.698 (1.4)

Notes: Figures in parenthesis are t-ratios. ***, ** and * denote statistically significant at the 1%, 5% and 10% levels, respectively, on the basis of a two-tail test.

Investment in human capital was boosted through the *Seventh and Eighth Five Year Plans (1988-1993 and 1993-1998)* (Govt. of Pakistan, 1987, 1994). Thus, all provinces exhibited generally positive trends in the literacy rate, nutritional status and medical services for human beings, and animal health services through treatment and vaccination. Growth in legal services was considerable in Punjab and Balochistan, while it was negligible in the rest. In respect of animal health (number of livestock treated), Balochistan excelled of all provinces, while the same in Punjab was negligible and statistically insignificant at the 10% level. Conversely, extension services for both livestock and crops declined in all provinces except Balochistan, where change is negligible. Research services for livestock increased in Punjab and KP but declined in Sindh and Balochistan. Research services for crops went up in Punjab and declined in the rest. Mechanization increased substantially and significantly in Punjab and Balochistan but did not change significantly in Sindh and KP. The road network per unit of crop and livestock output deteriorated in Sindh and Balochistan, but improved significantly in the other two provinces.

c) Estimates of Impacts of Determinants on TFP

Following Rosegrant and Evenson (1993), the combined TFP index was regressed against the above referred determinants in a log-linear way. The data were found to be suffering from heteroskedasticity problem, which was remedied by using the appropriate model of the econometric software, namely, EViews 6. The parameter estimates, representing elasticities, for the combined TFP for the four provinces are set out in Table III. The base elasticity (parameter) estimates are for Punjab and those for the other provinces were obtained by adding the interaction dummy estimates to the base and testing the difference from zero. Considerable differences for elasticity estimates and direction of change in the determinants are observed and explained below.

Table III : Model estimates for the determinants of TFP for Livestock

Variables	Coefficient	Standard error	z-statistic	*p*-value
Constant	-0.728	0.61	-1.19	0.23
Sindh dummy	-0.272	0.70	-0.39	0.70
KP dummy	1.59	0.65	2.43**	0.02
Balochistan dummy	4.063	2.09	1.96**	0.05
Tubewells (T)	0.008	0.08	0.11	0.92
Canals (C)	0.286	0.09	3.04***	0.00
Roads (RD)	0.037	0.03	1.19	0.23
Nutritional status (N)	0.357	0.10	3.41***	0.00
Literacy rate (L)	-0.048	0.02	-2.09**	0.04
Medical facilities (MF)	0.222	0.13	1.66*	0.10
Judicial services (J)	-0.051	0.01	-4.92***	0.00
Extension services for Livestock (E_L)	-0.219	0.03	-7.18***	0.00
Research services for Livestock (RS_L)	0.040	0.01	3.41***	0.00
Extension services for Crops (E_C)	0.247	0.04	5.90***	0.00
Research services for Crops (RS_C)	-0.098	0.03	-2.89***	0.00
Mechanization (ME)	0.009	0.04	0.25	0.80
Animal Health (AH)	0.006	0.02	0.24	0.81
Sindh*T	-0.061	0.09	-0.68	0.50
Sindh*C	-0.304	0.12	-2.59***	0.01
Sindh*RD	-0.118	0.03	-3.64***	0.00
Sindh*N	-0.311	0.12	-2.70***	0.01
Sindh*L	0.300	0.04	7.72***	0.00
Sindh*MF	-0.118	0.14	-0.87	0.38

Sindh*J	0.028	0.01	2.59***	0.01
Sindh*E_L	0.092	0.03	2.77***	0.01
Sindh*RS_L	-0.046	0.02	-2.45***	0.01
Sindh*E_C	-0.186	0.04	-4.36***	0.00
Sindh*RS_C	0.129	0.04	3.29***	0.00
Sindh*ME	-0.069	0.04	-1.63*	0.10
Sindh*AH	0.045	0.03	1.75*	0.08
KP*T	0.159	0.09	1.80*	0.07
KP*C	-0.170	0.13	-1.34	0.18
KP*RD	-0.077	0.05	-1.66*	0.01
KP*N	0.123	0.20	0.62	0.54
KP*L	-0.015	0.04	-0.38	0.70
KP*MF	-0.643	0.15	-4.17***	0.00
KP*J	0.051	0.01	4.83***	0.00
KP*E_L	0.258	0.04	7.15***	0.00
KP*RS_L	-0.016	0.02	-0.99	0.32
KP*E_C	-0.348	0.05	-7.56***	0.00
KP*RS_C	0.108	0.04	3.03***	0.00
KP*ME	0.054	0.04	1.27	0.20
KP*AH	0.039	0.05	0.80	0.42
KP*AV	-0.043	0.12	-0.36	0.72
Balochistan*T	0.077	0.19	0.41	0.68
Balochistan*C	-0.256	0.09	-2.98***	0.00
Balochistan*RD	-0.032	0.21	-0.15	0.88
Balochistan*N	0.204	0.07	2.83***	0.00
Balochistan*L	-0.760	0.20	-3.77***	0.00
Balochistan*MF	0.226	0.03	8.01***	0.00
Balochistan*J	0.376	0.06	6.26***	0.00
Balochistan*E_L	-0.085	0.07	-1.17	0.24
Balochistan*RS_L	-0.386	0.08	-4.91***	0.00
Balochistan*E_C	-0.108	0.23	-0.46	0.65
Balochistan*RS_C	0.316	0.18	1.74*	0.08
Balochistan*ME	-0.017	0.06	-0.30	0.77
Balochistan*AH	0.102	0.61	1.19	0.15

Note: *** significant at the 1 per cent level, ** significant at the 5 per cent level, * significant at the 10 per cent level on the basis of a two-tail test. $R^2 = 0.97$, Adjusted $R^2 = 0.95$ and DW statistic = 1.52.

The R^2 measuring overall goodness of fit is 0.97, showing that the model is well fitted to the data set used for the analytical purpose. The base coefficient estimate for intercept is less than zero and statistically insignificant (at the 10% level), which compares well with that reported by Ellahi *et al.* (2012). The same for Sindh is further low and those for KP and Balochistan are positive and statistically significant at the 5% level. It may be noted that in view of varying agro-climatic conditions, the pattern of livelihood in KP and Balochistan is different from that in Punjab and Sindh and the said results truly represent the inherent phenomenon in crop and livestock activities.

The base coefficient estimates for water resource development (T and C) bear positive signs as expected and that for tubewell is insignificant and close to zero, which may be attributed to spurious correlation between the said irrigation variables. The estimates on interaction dummies for water-scarce KP and Balochistan are above the base showing the need for tubewell water to irrigate crops and fruit trees. The estimate on C is significant at the 1% level and the same with interaction dummies for the rest of provinces are below the base showing that canal system in Punjab is better developed and impacting positively on the combined TFP as reported by Ellahi *et al.* (2010).

The base elasticity estimates for road infrastructure (RD) and nutrition (N) are positive and the latter is statistically significant at the 1% level, while a converse of this is true for Sindh where the coefficient estimates for the interaction variables are statistically significant at 1% level. These results are in line with the temporal change in RD as seen from Table II. In KP and Balochistan road variable bears negative sign, while

nutrition coefficient estimate is above the base estimates. In Punjab, a 1% increase in roads leads to about 0.04% increase in the combined crop-livestock TFP, while the effect of N is many times higher than that created by RD. The general tendency noted with respect to both N and RD is in line with those reported by Ellahi *et al.* (2010) in respect of TFP for crop production in the four provinces.

Literacy and medical facilities (L and MF) contribute positively in Punjab, but the estimate on both are statistically insignificant at 10% level), which is true for Sindh and KP as well but for literacy only. Interaction dummies with L and MF for Balochistan, being negative is consistent with expectations that its population is well spread (Ellahi *et al.*, 2010) and has the lowest access to these facilities as compared with the rest. Further, crop-livestock activities do not require literacy whose annual growth is the highest in Balochistan (Table II) but is negatively associated with the combined TFP. The impact of judicial services (J) for the combined TFP, as seen from coefficients on the base is negative and significant at 1% level and converse of this is true for the rest of provinces as seen for the interaction dummies. These results are consistent with those reported by Ellahi *et al.* (2010). It is noteworthy that in KP and Balochistan, a traditional system called *Jerga* (a jury comprising tribal heads) is effectively used for the settlement of disputes among the parties concerned. Thus, crop-livestock producers are more confident about their legitimate rights in KP and Balochistan as compared with those in Punjab.

As seen from Table II, public expenses incurred on extension services on livestock and crops generally retarded in most of provinces. However, extension activities in Punjab for crop sector (E_C) are well developed than those for livestock (E_L), which is reflected in positive and strong impact of the former on combined TFP, while a converse holds for the latter, i.e. E_L. On the other hand, in view of strongly uprising livestock industry a great deal of research efforts (RS_L) are being made which is reflected in strongly positive impact on the base coefficient estimate. The trend in crop research (RS_C) variable is significantly negative, which is consistent with results reported by Ellahi *et al.* (2010) and in contrast with the inferences drawn by Rosegrant and Evenson (1993). This observation need to be carefully interpreted because implications of research expenses for combined TFP growth are obtainable with a considerable time lag (Ali, 2005). Also, the results presented by Kiani *et al.* (2008) highlight the lagged relationship between expenses on RS_C and combined TFP growth and lend support to results presented in this study. The situation with respect to expenses on RS_C for the remaining provinces of Sindh, KP and Balochistan contrasts with that in Punjab and accord with the conclusions drawn by Rosegrant and Evenson (1993). As seen from Table III, the coefficient estimates for the rest all are above the base estimates for Punjab and generally significant at the 1% level. There seems a plausible explanation for this inference. Punjab has long benefited from RS_C and E_C in crop production (Heisey, 1990 and Byerlee, 1993), while it is yet to be accomplished in the other provinces and the said efforts are yielding good payoffs. Further, technological spillovers across provinces should have been achievable (Ellahi *et al.,* 2010) to boost agricultural output in Sindh, KP and Balochistan.

The base and other coefficient estimates for mechanical technology (ME) are generally insignificant at the 5% level. The base estimate and interaction dummy for KP bear positive and those for Sindh and Balochistan have negative signs. As per economic logic, it is expected that ME and TFP for livestock, comprising animal draught power, are substitutes as they replace each other, while ME and TFP for crops are complements. Therefore, the relationship of the combined TFP and ME is expected to be mixed as it is observed. The coefficient estimates for animal health (AH) for Punjab and others, though generally insignificant at the 5% level, have a positive impact on the combined TFP.

IV. Conclusion

The empirical analysis revealed that the development of irrigation and other economic infrastructure and policies for development of human capital had important implications for the growth of combined TFP. However, the benefits of growth are not evenly distributed across various provinces over the study period. The log-linear model used to decompose the combined TFP is well fitted to the data set used for analytical purposes.

The irrigation infrastructure is the most effective in triggering the growth of combined TFP in Punjab as compared with the rest of provinces. Road development and nutrition benefited producers in Punjab in a disproportionate way than those in other provinces. The relationship of the combined TFP and tractor technology is mixed as it is expected that tractor and livestock are substitutes, while tractor and crops are complements. The benefits of literacy and medical facilities are spatially well spread and motivate TFP growth across most of the provinces. However, judicial services tend to retard combined TFP in Punjab, while a converse is true for those having informal system of justice.

Well developed extension activities for crops in Punjab are is reflected in positive and strong impact on combined TFP than the same for livestock. On the other hand, uprising livestock industry is attracting a great deal of research efforts which is reflected in strongly positive impact on the base coefficient estimate. The trend in crop research variable is negative, which is consistent with results reported by Ellahi *et al.* (2010)

and in contrast with the inferences drawn by Rosegrant and Evenson (1993). This needs to be carefully interpreted as implications of research expenses for TFP growth are obtainable with a time lag (Ali, 2005 and Kiani *et al.,* 2008). The situation in other provinces contrasts with that in Punjab and accord with Rosegrant and Evenson's (1993) results. There seems a plausible explanation for this inference. Punjab has long benefited from research and extension for crops, while it is yet to be accomplished in the other provinces. Finally, coefficient estimates for animal health have a positive impact on combined TFP.

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