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Technology Transfer, Development, Deployment and Productivity Performance in Pakistan

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Abstract:

Productivity (TFP) performance is not only influenced by the direct effects of human capital, R&D (technology development)), embodied and disembodied forms of technology transfer and know-how through capital imports, FDI and use of foreign IPRs (technology transfer activities), but importantly is indirectly affected by components like the interactive effects of machinery and equipment imports, royalties and licenses fee payments, FDI, human capital and technology deployment. In this context, we analyzed internal technology building capabilities, trade-related technology transfer activities and foreign technology absorption capabilities. The ARDL technique demonstrates that stable long-run association exists amongst all the chosen variables. The results indicate that investment in human capital boost the TFP, in addition expenditures on R&D, imports of machinery are crucial determinants of TFP growth. Surprisingly, FDI appears with a negative sign but the indirect effect of FDI through its interaction with human capital is positive. This indicates that FDI in the presence of human capital plays a favourable role in enhancing TFP. Moreover, the imports of machinery directly and indirectly, in association with both human capital and R&D, increase the growth of TFP. These findings provide evidence that internal technology building capabilities enhances the TFP growth significantly; while, embodied form of technology transfer has a positive and significant impact on the growth of TFP; whereas, disembodied technology transfer exerts positive but statistically insignificant impact on TFP growth. Furthermore, the study lends support for the existence of strong foreign technology absorption capabilities.

Keywords: TFP growth, technology development, Trade-related technology transfers, technology deployment

1. INTRODUCTION

It has been found that only a fraction of growth in output can be explained by the growth in factors of production while the Solow

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residual which is known as total factor productivity (TFP) reflects technological advances. Total factor productivity is the proportion of output not explained by the factors of production used in production. Total factor productivity is not only influenced by the direct effects of human capital, R&D (i.e., internal technology building capabilities (technology development)), embodied & disembodied forms of technology transfer and know-how through capital imports, FDI and use of foreign intellectual property rights (i.e., trade-related technology transfer activities), but importantly indirectly is affected by components like the interactive effects of machinery and equipment imports, royalties and licenses fee payments, FDI, human capital and R&D (i.e., foreign technology absorption capabilities (technology deployment)). In this context, this study analyzes all the above mentioned direct and indirect effects: internal technology building capabilities, trade-related technology transfer activities and foreign technology absorption capabilities. Internal technology building capabilities may be defined as comprehending capabilities of choosing, assimilating, maintaining, using, designing, adapting and even creating technology [Huq (2006)]. While, the foreign technology absorption capabilities are the capabilities of the firms to understand the imported technology, modify it according to their own requirements and apply it domestically.

Several studies have been conducted to identify the conduits through which growth of TFP among different economies are interconnected. These studies put emphasis on the role of international trade and study the significance of imports of capital goods in internal production and enhancing TFP. Furthermore, they argue that economies more open to imports of foreign technology experienced more benefits from R&D conducted abroad. Moreover, these studies proved empirically that economies which have imported more machinery and equipment have realized faster growth in TFP and hence grew at a faster pace [Coe and Helpman (1995) and Coe, *et al.* (1997)].

The technology diffusion can also take place either in embodied form or in a disembodied way. Embodied technology transfer takes place through newly developed technology that is exemplified in foreign inputs and capital goods, which can be directly purchased, i.e., imports of new machinery and equipment from more advanced countries. While, the disembodied technological change can take place through transmission of new ideas and managerial skills, human quality and learning capability. Adaptation of imported technology, through imports of high-technology products and human capital acquisition are surely the significant channels of international technology diffusion and they have a robust impact on growth of TFP and hence on economic growth. Thus, anything which impedes technology transfer either in embodied form or in disembodied form will surely negatively affect the TFP growth. Other than above mentioned conduits of transfer of technology, foreign direct investment (FDI) and R&D efforts also have a positive impact on growth of TFP. The growth of TFP depends not only on a country's own R&D efforts but also on R&D efforts of its trading partners. Own R&D benefits economy in form of production of traded and non-traded goods and services; while, foreign R&D efforts benefits country in the form of imports goods and services, know-how about newly developed technologies and process. Thus, there may be significant interactions between various forms of imported technology and internal technology building capacities, such as domestic R&D efforts and human capital.

Within the above perspective, it is therefore desirable to examine the human capital, trade, R&D and TFP growth nexus to better understand the real sources of TFP growth and hence overall economic growth of the economy. This nexus needs to be studied more because the interrelationship amongst human capital, trade, R&D and TFP growth is likely to be a major issue for Pakistan in the time to come due to the escalating trade openness and the structure of imports that has been changing; witnessing an upward trend in imports of capital goods.

This study focuses on the human capital, trade, R&D and TFP growth relationship. Moreover, it also tests the foreign technology absorption capabilities (technology deployment). There are many studies relating to TFP in case of Pakistan such as Mahmood and Siddiqui (2000), Pasha, *et al.* (2002), Khan (2006), Hamid and Pichler (2009), Tufail and Ahmed (2015) but none has explored this area of research.

There are many international studies which provide support regarding diffusion of technology such as studies by Xu and Wang (2000), Mayer (2001), Xu and Chiang (2005). While, Teixeira and Fortuna (2010) have studied the nexus between trade, R&D, human capital and productivity. Based on co-integration analysis, they concluded that human capital stock has a stronger direct impact on TFP as compared to local R&D, whereas the indirect impact of R&D on TFP, through imports of machinery and equipment, is robust. The article concludes that international trade is the dominant contributor to TFP. Furthermore, they argued that the effect of FDI and imports of licenses and royalties is reliant on the institutional circumstances. Similarly, the role of human capital in promoting economic growth is assessed by Benhabib and Spiegel (1994). Human capital facilitates the adoption of imported technology and helps in innovating own technology. In this way human capital affects TFP. Moreover, growth is also promoted by the accumulation of human capital as argued by Benhabib and Spiegal (1994), Hall and Jons (1999) and Pasha, *et al.* (2002).

The theoretical and empirical work done aboard suggests the importance of the attempted work. Additionally, there exists many studies on Pakistan, but these studies do not address the issue of foreign technology absorption capacities, that has created a research gap. To bridge this gap, this study attempts to examine the impact of internal technology building capacities, trade-related technology transfer activities, and foreign technology absorption capabilities on TFP growth.

2. RESEARCH METHODOLOGY AND DATA

In this section, we discuss about the econometric methods which are used to estimate the model. We also discuss the estimation procedures and data and the sources of the data.

a. Methodological Framework

For the developing countries transfer of technology is a key source of technological advancement as suggested by neo-classical growth model. Technological improvement has led to renowned interest in trade-capital-technological change-growth nexus. Modern literature suggests that important supply side effects are triggered by trade which cause progress in industry and hence leads to economic growth. Thus, economies that import capital goods from more advance economies can increase their productivity levels and thus increase the pace of economic growth and can initiate their own innovation activities.

i. **The Growth Accounting Framework**

We find out the TFP using growth accounting framework. This approach gives more scope for disintegration of the contribution of factors inputs and the technological changes to economic growth.

Let us assume a general neo-classical production function.

$$Y_t = A_t . f(K_t , L_t) \quad ...(1)$$

Applying logarithm on both sides of Equ. (1), we get,

$$lnY(t) = lnA(t) + lnF[K(t), \quad L(t)] \quad ...(2)$$

Now differentiating with respect to time, and using $dln\, x(t)/dt = \dot{x}(t)/x(t)$ we get,

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{A}(t)}{A(t)} + \frac{F_k}{F[K(t), L(t)]} . \dot{K}(t) + \frac{F_l}{F[K(t), L(t)]} . \dot{L}(t) \quad ...(3)$$

Using Equ. (1), we obtain,

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{A}(t)}{A(t)} + \frac{A(t). F_k}{Y(t)} . \dot{K}(t) + \frac{A(t). F_l}{Y(t)} . \dot{L}(t) \quad ...(4)$$

The latter is the same as:

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{A}(t)}{A(t)} + \frac{A(t). F_k. K(t)}{Y(t)} . \frac{\dot{K}(t)}{K(t)} + \frac{A(t). F_l. L(t)}{Y(t)} . \frac{\dot{L}(t)}{L(t)} \quad ...(5)$$

If we assume that the capital and labour market are competitive then the share of the marginal product of the factor will be equal to their respective price. Then we have,

$$\frac{\Delta y}{\Delta K} = A \frac{\partial y}{\partial K} = AF_k , \qquad \frac{\Delta y}{\Delta L} = A \frac{\partial y}{\partial L} = AF_l$$

are the marginal product of capital and labour, respectively. So, Equ. (5) can be used to obtain Equ. (6),

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{A}(t)}{A(t)} + r.\frac{K(t)}{Y(t)}.\frac{\dot{K}(t)}{K(t)} + w.\frac{L(t)}{Y(t)}.\frac{\dot{L}(t)}{L(t)} \quad \text{... (6)}$$

where, 'r' and 'w' are the price of capital and labour, respectively. The $r.\frac{K(t)}{Y(t)}$ and $w.\frac{L(t)}{Y(t)}$ are the respective share of capital and labour in the total income, and in term of technological growth we can write Equ. (6) as:

$$\frac{\dot{A}(t)}{A(t)} = \frac{\dot{Y}(t)}{Y(t)} - r.\frac{K(t)}{Y(t)}.\frac{\dot{K}(t)}{K(t)} - w.\frac{L(t)}{Y(t)}.\frac{\dot{L}(t)}{L(t)} \quad \text{... (7)}$$

Using Equ. (7), we can easily calculate total factor productivity.

b. **Empirical Model**

In the current section, we estimate the long-run association amongst human capital, internal R&D activities, trade and productivity for the economy of Pakistan. We use the specification of the model as used by Teixeira and Fortuna (2010).

The general form of the model is,

$$TFP = f(HC, RD, IT) \quad \text{... (8)}$$

where, TFP represents total factor productivity. The data on TFP are not available for the economy of Pakistan; so, we estimate the TFP using growth accounting framework as described above. Total factor productivity estimation through growth accounting framework requires data on gross domestic product, capital stock, employed labour force, wages and interest rate, which are discussed in subsequent section.

Human Capital (HC). Different proxy variables are used in literature such as average years of schooling, adult literacy rate, expenditures on education, educational enrolment, international test scores and monetary values of human capital stock. Here, we use total government expenditure on education as proxy for human capital. Human capital affects TFP positively as it determines the nation's capacity to innovate novel machinery and equipment suitable to internal production as in Romer (1990a). Additionally, human capital enables the diffusion of foreign technology, hence increases productivity growth.

Expenditures on R&D (RD). R&D enables creation of new technology, new varieties products and improvement in existing ones which enhances per unit productivity and increases efficiency which in turn reduce per unit cost and hence increase economic growth.

Trade-related technology transfer activities (IT). It includes three variables which include imports of machinery and equipment, imports of royalties and licenses and foreign direct investment.

Imports of Machinery and Equipment (IME). We have used imports of non-electrical machinery and transport equipment as proxy for imports of machinery. Imports of machinery and equipment increases average productivity of firms using imported technology. It also increases the competition among the firms operating domestically. Thus, it fosters competition and economic growth.

Imports of Royalties and Licenses Fee (RLF). Royalties and licenses fee imports transfer relatively mature technology [Mowery and (Oxley 1995)]. Imported technology positively affect TFP of the host country as advanced foreign technology is acquired through imports, which embody advanced technology. Hence, TFP increases as it raises average productivity of a firm using advance technology; Furthermore, these firms can lead to enhanced competition among domestic firms [Mendi (2007)].

Foreign Direct Investment (FDI). Foreign direct investment increases TFP and boosts economic growth through number of conduits, such as spillover effects [Wang and Yu (2007)], transfer and diffusion of technology [Wang and Blomström (1992)]. Moreover, FDI enhances economic growth through gains in productivity [Girma (2005)] and mobility of labour from foreign markets to domestic markets. Hence, FDI increases productivity growth and enhances economic growth.

Based on Equ. (9), we can write the econometric model as,

$$TFP_t = \beta_0 + \underbrace{\beta_1\ HC_t + \beta_2\ RD_t}_{\text{Internal technology building capacities}} + \underbrace{\beta_3\ IT_t}_{\text{Trade-related technology transfer activities}} + \mu_t \quad \text{... (9)}$$

where, TFP_t represents the total factor productivity, HC_t, RD_t and IT_t shows human capital, expenditures on internal research and development and trade-related technology transfer activities for year t, respectively. The parameters β_1 , β_2 and β_3 are the TFP elasticities with respect to human capital, internal research and development and machinery/ FDI/ royalties and licenses imports, respectively and lastly, u_t represents residual term and is supposed to be $IIDN\ (0, \delta^2)$.

Teixeira and Fortuna (2010) proposed the following relationship to study the foreign technology absorption capacities,

$$TFP_t = \beta_0 + \underbrace{\beta_1 HC_t + \beta_2 RD_t}_{\text{Internal technology building capacities}} + \underbrace{\beta_3 IT_t}_{\text{Trade-related technology transfer activities}} + \underbrace{\beta_4 HC_t * IT_t + \beta_5 RD_t * IT_t}_{\text{Technological absorption capability}} + \mu_t \quad \text{... (10)}$$

If β_4 & β_5 turn out to be positive, then the indirect impact of human capital and R&D in association with through trade-related technology transfer activities on TFP is positively related to foreign technology acquisition. For the sake of simplicity and estimation purposes, Equ. (10) can be written as,

$$TFP_t = \beta_0 + \underbrace{\beta_1 HC_t + \beta_2 RD_t}_{\text{Internal technology building capacities}} + \underbrace{\beta_3 IME_t + \beta_4 RLF_t + \beta_5 FDI_t}_{\text{Trade related technology transfer activities}}$$

$$+ \underbrace{\beta_6 HC_t * IME_t + \beta_7\ RD_t * IME_t + \beta_8 HC_t * RLF_t + \beta_9\ HC_t * FDI_t}_{\text{Foreign technology absorption capabilities}} + \mu_t \quad \text{... (11)}$$

According to the economic theory, productivity is directly associated with technology imports, domestic R&D, human capital. Likewise, the interactions between human capital and technology imports $HC_t * IME_t$ and R&D and imported technology $RD_t * IME_t$, for instance, are expected to have positive signs.

c. **Data and Data Sources**

The data for the current study are collected from several sources which include various issues of Pakistan Economic Survey, World Development Indicator (WDI) by the World Bank, Handbook of Statistics on Pakistan Economy by the State Bank of Pakistan, Science & Technology Data Book by Pakistan Council for Science & Technology and IMF Balance of Payments Statistics. We used time series data from the 1964-2014; we could not go beyond because of non-availability of data; otherwise, the results could be more robust.

The data on TFP are not available for the economy of Pakistan; so, we estimate the TFP using growth accounting framework. Total factor productivity estimation through growth accounting framework requires data on gross domestic product, capital stock, employed labour force, wages and interest rate.

The data on GDP are obtained from Handbook of Statistics on Pakistan Economy. The study by Kemal and Ahmed (1992) provides estimates of capital stock till 1991, we have extended estimates until 2014 using the perpetual inventory method and employing a depreciation rate of 4%. In the literature usually 5% depreciation is used but we have used 4% depreciation rate, as 4% depreciation rate is used by Kemal and Ahmed (1992) which makes the data consistent with the capital stock generated by Kemal and Ahmed (1992). Moreover, Tufail and Ahmed (2015) also used 4% depreciation rate in the calculation capital stock based on perpetual inventory method.

The procedure for generating capital stock is as follow,

$$K_t = I_t + (1 - \delta)K_{t-1} \qquad \text{...(12)}$$

Where, K_t represents current period capital stock, I_t is gross investment in time t, while, δ is depreciation rate. The initial capital stock is generated using the following equation,

$$K_t = \frac{I_t}{\delta + g} \qquad \text{...(13)}$$

where, g is average growth rate. Rewriting Equ. (21) for $t - 1$ as,

$$K_{t-1} = I_{t-1} + (1-\delta)K_{t-2} \quad \text{... (14)}$$

Now, substituting Equ. (14) in Equ.(12), we get,

$$K_t = I_t + (1-\delta)I_{t-1} + (1-\delta)K_{t-2} \quad \text{... (15)}$$

By continuous substation, we obtain,

$$K_t = \sum_{i=0}^{n-1}(1-\delta)^i I_{t-1} + (1-\delta)^n K_{t-2} \quad \text{... (16)}$$

where, *n* shows the number of years and as the number of years increases the value of initial capital stock approaches to zero.

The employed labour force data are taken from various publications of Pakistan economic survey. While, the study by Irfan (2009) is utilized to obtain data on wages. This study provides data on wages from the 1991-2007, beyond 2007 Labour Force Survey of Pakistan is used to obtain wages data; whereas, the data before the 1991 are taken from International Labour Organization (ILO) for manufacturing sector of Pakistan. We adjusted below this data by 5% to have make data more representative for average wage of the economy. The difference between the data reported by Irfan (2009), i.e., average wage for the whole economy and the ILO data, i.e., wages for manufacturing sector only, stood at about 5%. Which provide us to justification to make adjustment in ILO data. Thus, the final series for wages is obtained by subtracting an amount equivalent to 5% from each value. Finally, the interest rate data are obtained from IMF International Financial Statistics. Money market interest rate is used for the reward of capital.

For human capital, different proxy variables are used in literature such as average years of schooling, adult literacy rate, expenditures on education, educational enrolment, international test scores and monetary values of human capital stock. Here, we used total government expenditure on education as proxy for human capital. The data source is various issues of Pakistan Economic Survey.

The data regarding expenditures on R&D have been obtained from different publications of science and technology data books published by Pakistan Council for Science and Technology (PCST) Islamabad. The data from the 1970-80 on R&D used in the current study are from the UNESCO data book as reported in science and technology data book. Furthermore, the data from the 1964-69 is generated using five year moving average method as the data is not available for the said period. This is the first attempt that R&D expenditures data collected from PCST Islamabad is being used for such a long period.

Trade-related technology transfer activities include three variables, i.e., imports of machinery and equipment (IME), imports of royalties and licenses (RLF) and foreign direct investment (FDI). The data on IME are taken from various publications of Pakistan economic survey. We have used imports of non-electrical machinery and transport equipment as proxy for imports of machinery. The data regarding RLF have been acquired from IMF balance of payments (BOP) Statistics, which is available from the 1993; whereas, we obtain data from the 1965-69 from Radhu (1973). Moreover, we interpolate remaining data the said variable. This is the first time RLF data are being used in any study. Lastly, the data on FDI inflows are taken from the World Bank's World Development Indicator.

Finally, we converted all the data in Pakistan Rupee and then using GDP deflator, we transformed the given series into the constant 1980-81 prices except TFP which is growth form.

3. RESULTS AND DISCUSSION

In this section, we present and discuss the results of different techniques applied to data. Moreover, we discuss the results of ARDL model and its robustness.

a. Testing for Outliers

Split Sample Skewness Based Boxplot (SSSBB) developed by Adil (2012) is used to check outliers in data set. The results for detecting outliers are shown Table 1. Using SSSBB technique to detect outlier we find two observations less than lower bound value in import of machinery and one observation greater than upper bound value FDI inflow variable. The outliers in machinery imports and FDI are in the year 1971-

72 and 1972-73 and 2007, respectively. While, the outliers in case of imports of machinery variable are in the year 1971-72 and 1972-73; which, show the drop in imports of machinery. In the 1971-72, the drop in machinery imports were due to the conditions like recession, cost limitations, dearth of power, labour disturbance and other factors of uncertainty in the aftermath of war. In the 1972-73, the import prices increased and it became unattractive for the importers to purchase from abroad. Thus, these two observations are adjusted to the mean value of the series in order to get more precise estimates.

The outlier in FDI inflow is in year 2007 which is also found to be a true observation as FDI inflows peaked in 2007 in the entire history of Pakistan. But for the precision of results, we have adjusted this observation to the average of the series. Furthermore, we found no outliers in all other variables included in the paper.

Table 1. Detection of Outliers

	TFP	HC	RD	IME	RLF	FDI
Q_1L = 12.5th percentile	0.002486	1199.937	361.0987	4663.262	79.26318	235.4044
Q_3L = 37.5th percentile	0.015941	1850.92	571.417	5605.75	92.68175	520.173
IQRL =Q3L-Q1L	0.013455	650.9826	210.3183	942.4879	13.41857	284.7685
Q_1R = 62.5th percentile	0.057584	4463.398	3279.953	33848.32	618.2679	8433.606
Q_3R = 87.5th percentile	0.075438	5047.362	5480.478	45258.86	756.4863	18039.66
IQRR $=Q_3R-Q_1R$	0.017854	583.9634	2200.525	11410.54	138.2184	9606.058
$L = Q_1L - 1.5 * IQRL$	-0.0177	223.4631	45.62134	3249.531	59.13531	-191.748
$U = Q_3R + 1.5 * IQRR$	0.102218	5923.307	8781.266	62374.68	963.8139	32448.75
Outliers Detected	0	0	0	2	0	1

b. **Testing for Structural Break in Data**

Before applying the unit root tests, we check for structural break in data as we are using data from 1964; thus, we need to check for breakpoint in data series for the year 1971. We used two different tests to check whether there is any structural break in data, i.e., Chow test and

Quandt-Andrews unknown breakpoint test. Chow test requires a specific point to check for structural break in data. Using chow test, we test for structural break in the year 1971. The results of two tests are displayed in Table 2. The Chow test shows breakpoint in the data as we can reject H_0. Similarly, the Quandt-Andrews unknown breakpoint test signifies structural break in data set as the probability for F-statistic is greater than 0.05, hence we reject H_0. Thus, we can conclude from these two tests that there are structural breaks in data.

Table 2. Structural Break Test

	F-statistic	Prob.
Chow Test (1971)	2.862845	0.0208
Quandt-Andrews unknown breakpoint test	6.967301	0.0000

c. **Unit Roots Test**

Before the application of co-integration analysis, we need to check the order of the variables involved in the analysis. To check whether the time series data used to estimate model is stationary or not, we have used minimum LM unit root test with one structural break to determine unit root in the time series variables. We have estimated LM statistic for each variable in the model with drift and trend at level and 1st difference. The test results are in Table 3.

In LM unit root test with one structural break, we test the null hypothesis that "series has unit root" against the alternative hypothesis that "series is stationary". The results of LM unit root test shows that *HC*, *IME*, *RLF*, *FDI*, *HC*IME and HC*RLF* are stationary at level while *TFP*, *RD*, *RD*IME* and *HC*FDI* have unit root at level and are stationary at first difference as revealed in Table 3.

As LM unit root test shows that some of the variables are stationary at the level, i.e., *I(0)* means that integrated of order 0. Whereas, other variables have unit-root at level and are stationary at first difference, i.e., they *I(1)*. So, ARDL Technique can be applied to check for long run relationship between variables.

Table 3. Minimum LM Unit Root Test for One Structural Break

Variable	Level		First Difference		Decision
	Intercept & Trend	t-Stat	Intercept & Trend	t-Stat	
TFP	-1.1065	-3.8172	-2.1617*	-6.4127	*I(1)*
LnHC	-1.7500**	-4.6514			*I(0)*
LnRD	-0.7192	-3.7573	-1.2689**	-4.2435	*I(1)*
LnIME	-0.9513**	-4.8848			*I(0)*
LnRLF	-1.0510**	-4.5100			*I(0)*
LnFDI	-1.8910*	-5.2001			*I(0)*
lnHC*lnIME	-1.3369***	-4.3676			*I(0)*
lnRD*lnIME	-0.7275	-4.0670	-3.1123**	-4.9956	*I(1)*
lnHC*lnRLF	-1.0350**	-4.5270			*I(0)*
lnHC*lnFDI	-1.0973	-3.4367	-1.9127*	-5.9946	*I(1)*

Critical values when considering intercept and trend ranges between (-4.17 to -4.21), (-4.45 to -4.51) and (-5.05 to -5.11) at the 10%, 5% and 1% significance level, respectively.
***, **, * indicates significance at 10%, 5% and 1% levels.

Autoregressive Distributed Lag (ARDL) Model

The results of ARDL model is shown in Table 4. We estimated three models and reported the standard errors and p-values for each estimated coefficient. Wald restriction test is used to confirm the existence of long-run relationship among the given variables.

Table 5 displays the critical values for Wald test which are obtained from Pesaran, *et al.* (2001) unrestricted intercept and no trend (case iii); while, the estimated F-values for Wald test are shown in Table 6. Furthermore, different diagnostic tests are applied to check the robustness of the model which are reported in Table 7.

Three ARDL models are estimated utilizing data from the 1964 to 2014. All the variables are included in model-1 except *HC*RLF*; whereas in model-2, we have included the interaction between human capital and imports of royalties and licenses and excluded the direct variable royalties and licenses imports, i.e., *RLF*. In contrast to Models 1 and 2, in model-3 we excluded variable *RLF* as well as *HC*RLF*. Moreover, a dummy variable is included in all three models, i.e., *D_SBREAK1971*, to capture the effect of structural break. The coefficient on dummy variable is negative and insignificant in all three models

Table 4. ARDL Results

DTFP is the dependent variable									
Variable	Model 1			Model 2			Model 3		
	Coefficient	SE	Prob.	Coefficient	SE	Prob.	Coefficient	SE	Prob.
TFP_1	-0.440528	0.198307	0.0360	-0.449391	0.198102	0.0326	-0.484426	0.190451	0.0173
Constant	-0.1354	0.079964	0.1033	-0.133864	0.081543	0.1137	-0.14489	0.067676	0.0418
ln HC_1	0.10446	0.033514	0.0047	0.10271	0.031959	0.0037	0.105436	0.030494	0.0019
ln RD_1	0.028704	0.012951	0.0364	0.028868	0.012612	0.0312	0.026067	0.01199	0.0390
ln IME_1	0.017701	0.012022	0.1539	0.017762	0.011543	0.1370	0.017606	0.009307	0.0697
ln RLF_1	0.001238	0.006364	0.8474						
ln FDI_1	-0.00807	0.00167	0.0001	-0.007999	0.001683	0.0001	-0.007736	0.001624	0.0001
ln (HC*IME)_1	0.004266	0.004817	0.3846	0.00369	0.004786	0.4483	0.004857	0.004643	0.3051
ln (RD*IME)_1	0.039998	0.011607	0.0021	0.039999	0.011711	0.0023	0.037912	0.010813	0.0017
ln (HC*RLF)_1				0.001421	0.006348	0.8247			
ln (HC*FDI)_1	0.001289	0.007316	0.8616	0.001312	0.00758	0.8640	0.000512	0.006415	0.9370
DTFP_1	-0.443106	0.205777	0.0416	-0.438311	0.205752	0.0436	-0.396971	0.194973	0.0521
DTFP_2	-0.116861	0.131425	0.3827	-0.118419	0.129967	0.3713	-0.106405	0.127003	0.4098
DlnHC	0.092083	0.02554	0.0014	0.091202	0.025206	0.0014	0.097231	0.022052	0.0002
DlnHC_1	0.007544	0.021257	0.7258	0.006414	0.021617	0.7692	0.013339	0.020293	0.5168
DlnRD	0.011092	0.011426	0.3413	0.009672	0.011605	0.4128	0.013617	0.01089	0.2223
DlnRD_1	-0.010186	0.011268	0.3750	-0.011525	0.011614	0.3309	-0.007733	0.010598	0.4721
DlnIME_1	0.005337	0.008716	0.5461	0.00579	0.008829	0.5182	0.003687	0.007829	0.6416
DlnFDI	-0.002942	0.001265	0.0288	-0.00292	0.001271	0.0306	-0.002941	0.001248	0.0263
DlnRLF	0.011287	0.009817	0.2616						
D(lnHC*lnIME)	-0.001304	0.003407	0.7052	-0.001585	0.003345	0.6399	-0.000455	0.003073	0.8834
D(lnRD*lnIME)	-0.004953	0.006619	0.4615	-0.005208	0.00659	0.4371	-0.004827	0.00628	0.4490
D(lnRD*lnIME)_1	0.01117	0.006134	0.0811	0.011317	0.006172	0.0791	0.010511	0.00586	0.0845
D(lnHC*lnFDI)	0.008684	0.005257	0.1116	0.008462	0.005384	0.1291	0.00835	0.004976	0.1053
D(lnHC*lnRLF)				0.010251	0.008293	0.2284			
D_SBREAK1971	-0.016137	0.014392	0.2733	-0.016513	0.013201	0.2230	-0.018692	0.012775	0.1554
R^2		0.875988			0.876931			0.869075	
R-bar-squared		0.757143			0.758991			0.763329	
F-statistic		7.370851			7.435357			8.218461	
Prob(F-statistic)		0.000003			0.000003			0.000001	
DW stat		2.019499			2.017271			1.962892	

indicating that the effect of structural break has negative but insignificant impact on the economy.

Table 5. Pesaran, *et al.* (2001) Value for F-statistics (Unrestricted Intercept and No Trend (case iii))

Level of Significance	Model 1 & 2		Model 3	
	Lower bound values	Upper bound value	Lower bound values	Upper bound value
1%	2.65	3.97	2.79	4.10
5%	2.14	3.30	2.22	3.39
10%	1.88	2.99	1.95	3.06

Table 6. Wald Restriction Test

	Model 1	Model 2	Model 3
F-statistics	5.71	5.72	6.66
Prob(F-statistics)	0.0003	0.0003	0.0001

The Wald test results for the model-1 indicate that F-calculated is greater than upper bound value at 1% level of significance obtained from Pesaran, *et al.* (2001) that is 5.71 > 3.97. Thus, we reject the null hypothesis of no co-integration and conclude that there exists long-run relationship among given variables of model-1. Similarly, the null hypothesis of no co-integration can be rejected for Models 2 and 3, as the calculated F-value is greater than upper value provided by Pesaran, *et al.* (2001). Hence, there is long-run association between the variables. All the diagnostic tests stipulate that all three models are robust as there is no problem of autocorrelation in all three models. We have applied Breush- Godfrey Serial Correlation LM test to check autocorrelation in the estimated models. The p-values for Models 1, 2 and 3 are 0.8938, 0.9235 and 0.9684, respectively, as shown in Table 7, which direct that we cannot reject the null hypothesis of no autocorrelation for all three models, so we conclude that all three models are free from the problem of serial correlation.

Normality of all three models is checked by applying Jacque-Bera (JB) normality test. The p-value for all three models is greater than 0.05 as shown in Table 7, which specifies that null hypothesis of normal distribution cannot be rejected. Therefore, residuals in all the models have normal distribution.

To check the problem of hetroskasticity, we have applied Breusch-Pagan-Godfrey (BPG) test and ARCH test. The results of both tests are reported in Table 7. Both tests point out that residuals of all three models are homoscedastic as the p-value is greater than 0.05 for all three models. Thus, we cannot reject the null hypothesis of homoscedasticity.

Finally, we applied Ramsey RESET test to check whether model is correctly specified. Table 7 shows the results for model specification. The null hypothesis and alternative hypothesis for Ramsey RESET test are:

$$H_0: Model\ is\ correctly\ Specified$$
$$H_1: Model\ is\ incorrectly\ specified$$

Table 7. Diagnostic Test Summary

Test Applied	Model 1	Model 2	Model 3
	F-statistics Prob.	F-statistics Prob.	F-statistics Prob.
Breush- Godfrey Serial Correlation LM test	0.112874 (0.8938)	0.079923 (0.9235)	0.032166 (0.9684)
Jacque-Bera Normality test	1.048274 (0.5921)	0.937476 (0.6258)	0.798688 (0.6708)
Hetroskasticity: Breusch-Pagan-Godfrey test	0.843198 (0.6574)	0.949565 (0.5482)	0.890442 (0.6030)
Hetroskasticity: ARCH test	0.516422 (0.4761)	0.304561 (0.5838)	0.040473 (0.8415)
Ramsey RESET test	0.597349 (0.4475)	0.727756 (0.4024)	0.168895 (0.6846)

The results of specification test show that p-values are greater than 0.05 for all three models. Thus, we cannot reject the null hypothesis and conclude that model is correctly specified.

i. **Model 1**

The results presented in Table 4 can be re-written in form of equation for the model-1 as,

$$TFP_t = 0.237\, Hc_t + 0.065\, RD_t + 0.040\, IME_t + 0.003\, RLF_t - 0.018\, FDI_t + 0.010\, (HC^*IME)_t + 0.091\, (RD^*IME)_t + 0.003\, (HC^*FDI)_t \quad \text{... (17)}$$

Equ. (17) represents long-run estimated coefficients for model-1.

ii. **Model 2**

Now, we re-write model-2 and obtain long-run coefficients for model-2 as,

$$TFP_t = 0.229\, Hc_t + 0.064\, RD_t + 0.040\, IME_t - 0.018\, FDI_t + 0.008\, (HC^*IME)_t + 0.089\, (RD^*IME)_t + 0.003\, (HC^*RLF)_t + 0.003\, (HC^*FDI)_t \quad \text{... (18)}$$

Equ. (18) shows long-run estimates for model-2.

iii. **Model 3**

Finally, we obtain long-run estimates for model-3 as follows,

$$TFP_t = 0.218\, Hc_t + 0.054\, RD_t + 0.036\, IME_t - 0.016 FDI_t + 0.010\, (HC^*IME)_t + 0.078\, (RD^*IME)_t + 0.001\, (HC^*FDI)_t \quad \text{... (19)}$$

Long-run estimates for model-3 are presented in Equ. (19).

iv. **Interpretation of Results**

The long-run results for Models 1, 2 and 3 are reported in Equs. 17, 18 and 19, respectively. The results of model-1 shows that IME, RLF, HC*IME and HC*FDI have positive but statistically insignificant relation with TFP. On the other hand, FDI has a negative and significant relation with TFP. Whereas, human capital, RD and RD*IME have a positive and significant relationship with TFP. In the first model, we have not included the interaction term HC*RLF.

In the second model all the variables have expected sign except FDI which have negative and statistically significant relation with TFP. Moreover, we have included the interaction term HC*RLF that has a positive sign as expected but is insignificant. Furthermore, we have excluded the RFL in this model. Finally, in third model both RLF and HC*RLF are not included in estimation. Whereas, all the signs are as expected. Now we interpret results in more detail.

Equs. 17, 18 and 19 shows long-run estimates for the models 1, 2 and 3, we start interpreting our results with human capital. The sign of human capital is positive, which confirms the results of Mahmood and Siddiqui (2000), Khan (2006) and Tufail and Ahmed (2015). The coefficient of human capital is 0.237 in the first model which indicates that a 1% increase in human capital will increase total factor productivity of Pakistan by 0.237%. Similarly, in model-2 the coefficient of human capital is 0.229, which shows a 0.229% increase in TFP in case of 1% enhancement in educational expenditures. Finally, the long-run coefficient of human capital in model-3 is 0.218, which directs that a 1% surge in educational expenditures will raise TFP by 0.218%.

The coefficient of R&D in the first model is 0.065, which specifies that TFP will grow by 0.065% if expenditures on R&D is raised by 1%. In the second model, the estimated coefficient for R&D is 0.064 which postulates that a 1% in R&D expenditure will surge TFP by 0.064%. Lastly, the coefficient in model-3 for R&D is 0.054 showing a 0.054% increase in TFP in case if internal R&D expenditures are raised by 1%, which is significant and high as compared to models 1 and 2. The results of domestic R&D expenditures are according to a priori expectations. Furthermore, these results confirm the results of Coe and Helpman (1995) and Mendi (2007) that local R&D effect TFP positively.

Technology transfers from more advance countries to developing countries through trade-related technology transfer activities, we have included three variables for it, one is import of machinery and equipment, other is royalties and licenses payments to use the foreign technology and third one is FDI. The results in model-1 reveal that machinery and equipment imports affect TFP positively and significantly. Coe and Helpman (1995) and Coe, *et al.* (1997) suggested that foreign trade in form of imports of machinery and equipment has been a real transferor of knowledge. Moreover, capital goods trade is a strong determinant for global technology diffusion [Xu and Wang (2000)]. In case of agriculture and manufacturing sectors of the economy of Pakistan, Tufail and Ahmed (2015) found a positive relationship between imports of machinery and TFP growth. The coefficient for machinery imports in first two models is 0.040, which shows that a 1% increase in machinery and equipment imports will boost the TFP by 0.040%, while for third model it is 0.036. The results for royalties and licenses fee payment that is disembodied technology transfer is not very encouraging as the estimated coefficient is positive but insignificant, which specify a direct impact of disembodied technology transfer on the economy.

It is generally believed and also suggested by the literature that FDI is a significant channel through which technology transfers from advanced countries to less developed nations. Also, it has some positive externalities as discussed before that has a beneficial impact on growth of any economy. In case of Pakistan, all three models direct that FDI has a negative and significant impact on the economy of Pakistan which shows that it is growth retarding. This result is in line with some of the previous studies conducted for Pakistan such as Atique, *et al.* (2004), Khan (2007) and Falki (2009). The negative association amongst FDI and TFP designates the deficiency of basic infrastructure and related skills to absorb the technology, which comes through FDI. This dearth of skills and inefficiencies prevent spillover effect of FDI on TFP growth and hence economic growth of Pakistan. Foreign direct investment mostly carries capital-intensive techniques; while, emerging countries are labour abundant. Thus, these countries need sufficient amount of time for shifting from labour-intensive to capital-intensive techniques that is why FDI is growth retarding in developing economies like Pakistan. Furthermore, in case of Pakistan the negative association between FDI and TFP growth may be due to lack of transfer of technology as FDI has not transferred technology that enhances skills; in this regard the best example is the automobile industry. Moreover, foreign direct investment does not wield a robust, independent effect on growth [Carkovic and Lavine (2002)], poor economies are unable to exploit FDI [Blomstrom, Lipsey, and Zejan (1994)] and spillover effects can be enjoyed by a recipient country only if the efficiency and improvement of internal financial sector at certain minimum level are achieved [Khan (2007)].

The foreign technology absorption capability of the economy of Pakistan is tested by analyzing the indirect impact of machinery and equipment imports through human capital and R&D, indirect impact of royalties and licenses fee payments through human capital and indirect impact of FDI through human capital. All three models show that interaction between human capital and machinery imports is positive and statistically insignificant. The coefficients of HC*IME in models 1, 2 and 3 are 0.010, 0.008 and 0.010 indicating that a 1% increase in HC*IME will boost the TFP by 0.010, 0.008 and 0.010 percent, respectively. This positive association between human capital and embodied technology imports suggests that human capital appears to be crucial for imported technology to be efficiently adopted in the sense that highly educated workers are able to adapt more rapidly to the new, presumably more sophisticated technology imported from foreign countries. The positive link between HC*IME and TFP growth is similar with findings of Mayer (2001) that the imports of machinery along with human capital have strongly significant and positive effect on cross country growth differences.

The interactive variable RD*IME affects TFP directly and significantly at 1% level of significance in all three models. The estimates for RD*IME are 0.091, 0.089 and 0.078, respectively, for the three models. These estimates specify that TFP increases by 0.091, 0.089 and 0.078 percent as RD*IME increases by 1%, respectively, in models 1, 2 and 3. Thus, in case of Pakistan the imports of machinery and equipment is complemented by local expenditures on R&D. R&D spillovers embodied in capital goods trade has a substantial positive influence on a country's TFP [Xu and Wang (2000)]. The indirect impact of R&D on TFP, through imports of machinery and equipment, is robust [Teixeira and Fortuna (2010)].

The indirect impact of royalties and licenses fee payment through human capital is analyzed in model-2. The estimated coefficient for HC*RLF is positive but statistically insignificant which shows that indirect effect of disembodied technology transfer in form of imports of royalties and licenses fee payment is not playing a significant role in enhancing TFP growth of the economy of Pakistan.

The interaction term between human capital and FDI appears with a positive sign but is statistically insignificant in all three models. These positive results are in line with Hermes and Lensink (2003) and

Borensztein, *et al.* (1998), which show that inward FDI is firmly reliant on the institutional circumstances of the recipient country. Specifically, foreign direct investment is positively linked with economic performance only if a nation has achieved a certain level of educational expenditures, thus verifying the "absorptive capacity" hypothesis. They further found that for countries having a very low level of human capital the direct impact of FDI is negative [Borensztein, *et al.* (1998)]. The estimated coefficient of HC*FDI in all three models is 0.003, 0.003 and 0.001 showing a 1% increase in HC*FDI will increase TFP by 0.003, 0.003 and 0.001 percent, respectively. Thus, FDI impacts on TFP growth positively only if properly trained or educated human resources are available in the host country.

Error Correction Model

The results of error correction model for all three models are presented below in Table 8 and interpreted in subsequent section.

i. **ECM Model 1**

$$\begin{aligned}\Delta TFP_i = {} & 0.001949 - 0.006408\, D\_SBREAK1971 - 0.071094 \Delta TFP_{t-1} \\ & + 0.068969\, \Delta lnHc_t + 0.003402\ \Delta lnRD_t \\ & + 0.007362\, \Delta lnIME_t + 0.016337\, \Delta lnIME_{t-1} \\ & - 0.000149\, \Delta lnFDI_t + 0.004585\, \Delta lnRLF_t \\ & - 0.004287\, \Delta(lnHC^* lnIME)_t \\ & - 0.003404\, \Delta(lnRD^* lnIME)_t \\ & + 0.007503\, \Delta(lnHC^* lnFDI)_t \\ & - 0.551492\, ECM_{t-1} \qquad \dots (20)\end{aligned}$$

ii. ECM Model 2

$$\begin{aligned}\Delta TFP_i = {} & 0.007257 - 0.011085\, D_{SBREAK1971} - 0.038906\, \Delta TFP_{t-1} \\ & - 0.01153\, \Delta lnHc_t .005983\ \Delta lnRD_t + 0.000893\, \Delta lnIME_t \\ & + 0.000361\, \Delta lnFDI_t - 0.00805\, \Delta(lnHC^* lnIME)_t \\ & - 0.008128\, \Delta(lnRD^* lnIME)_t \\ & + 0.016339\, \Delta(lnHC^* lnFDI)_t \\ & + 0.00000000307\, \Delta(lnHC^* lnRLF)_t \\ & - 0.599487\, ECM_{t-1} \qquad \dots (21)\end{aligned}$$

i. ECM Model 3

$$\Delta TFP_i = 0.001771 - 0.006173\,D\_SBREAK1971 - 0.064933\,\Delta TFP_{t-1} + 0.068982\,\Delta lnHc_t + 0.004757\ \Delta lnRD_t + 0.006679\,\Delta lnIME_t + 0.016735\,\Delta lnIME_{t-1} - 0.000241\,\Delta lnFDI_t - 0.004307\,\Delta(lnHC^{*}lnIME)_t - 0.003789\,\Delta(lnRD^{*}lnIME)_t - 0.000533\,\Delta(lnRD^{*}lnIME)_{t-1} + 0.007909\,\Delta(lnHC^{*}lnFDI)_t - 0.553036\,ECM_{t-1} \quad \dots (22)$$

ii. Interpretation of Error Correction Model

The estimated ECM term for all three models is negative and statistically significant at 1% level of significance in all three models. The negative sign specifies that model converges to the long-run equilibrium. The magnitude of ECM term is fairly high indicating higher speed of adjustment back to equilibrium. Specifically, the magnitude of ECM term for all three models is 0.552, 0.599 and 0.553, respectively, showing that about 55.2%, 59.9% and 55.3% of disequilibria in TFP growth of the preceding year adjusts back to long-run equilibrium in the present period, respectively. Additionally, it will take almost 7 years to completely adjust the disequilibrium in TFP growth.

All the tests applied to ECM models are reported in Table 9 confirms that all three models are $IIDN(0, \delta^2)$ as the results of diagnostic tests reveals that the residuals of all three models are serially uncorrelated, normally distributed and homoskesdastic. Furthermore, the specification test applied indicates that models are specifically sound as there is no misspecification in the models. Thus, the results of the models are valid and reliable.

The coefficient of human capital is positive and statistically significant in model-1 and model-3; while, it is negative and insignificant in model-2 as the human capital is considered to be long-run investment. The signs of FDI, interaction between human capital & machinery imports and the interaction between R&D and machinery imports are negative specifying a burden on the economy in short-run. Whereas, sign of all the remaining variables is same as long-run signs.

Table 1. Error Correction Model

DTFP is the dependent variable

Variable	Model 1			Model 2			Model 3		
	Coefficient	SE	Prob.	Coefficient	SE	Prob.	Coefficient	SE	Prob.
Constant	0.001949	0.007258	0.7898	0.007257	0.008447	0.3958	0.001771	0.007448	0.8134
D_SBREAK1971	-0.006408	0.007633	0.4067	-0.011085	0.008818	0.2166	-0.006173	0.007994	0.4450
DTFP_1	-0.071094	0.102408	0.4920	-0.038906	0.139879	0.7825	-0.064933	0.109243	0.5560
DlnHC	0.068969	0.017035	0.0003	-0.011530	0.021063	0.5874	0.068982	0.019168	0.0010
DlnRD	0.003402	0.010813	0.7549	0.005983	0.013115	0.6509	0.004757	0.010865	0.6641
DlnIME	0.007362	0.006431	0.2599	0.000893	0.00694	0.8983	0.006679	0.006458	0.3079
DlnIME_1	0.016337	0.004827	0.0017				0.016735	0.005769	0.0063
DlnFDI	-0.000149	0.000786	0.8503	0.000361	0.000892	0.6877	-0.000241	0.000939	0.7990
DlnRLF	0.004585	0.009185	0.6207						
D(lnHC*lnIME)	-0.004287	0.002493	0.0941	-0.008050	0.002667	0.0046	-0.004307	0.002453	0.0876
D(lnRD*lnIME)	-0.003404	0.004918	0.4933	-0.008128	0.005534	0.1503	-0.003789	0.005004	0.4539
D(lnRD*lnIME)_1							-0.000533	0.005657	0.9254
D(lnHC*lnFDI)	0.007503	0.004024	0.0704	0.016339	0.004229	0.0004	0.007909	0.004202	0.0679
D(lnHC*lnRLF)				3.07E-09	1.20E-09	0.0150			
ECM_1	-0.551492	0.135988	0.0003	-0.599487	0.15856	0.0006	-0.553036	0.150763	0.0008
R^2		0.77479			0.68753			0.77203	
R-bar-squared		0.69972			0.59464			0.69604	
F-statistic		10.32091			7.40101			10.1595	
Prob(F-statistic)		0.0000			0.000002			0.0000	
DW stat		2.25231			2.18524			2.21684	

Table 2. Diagnostic Test Summary

Test Applied	Model 1	Model 2	Model 3
	F-statistics Prob.	F-statistics Prob.	F-statistics Prob.
Breush- Godfrey Serial Correlation LM test	1.373589 (0.2669)	1.125823 (0.3358)	1.390061 (0.2629)
Jacque-Bera Normality test	0.061368 (0.9698)	0.717607 (0.6985)	0.041215 (0.9796)
Hetroskasticity: Breusch-Pagan-Godfrey test	0.821882 (0.6275)	0.841416 (0.6016)	0.916595 (0.5407)
Hetroskasticity: ARCH test	0.303165 (0.5846)	0.050287 (0.8236)	0.340350 (0.5625)
Ramsey RESET test	1.653272 (0.2070)	2.278011 (0.1399)	1.852550 (0.1822)

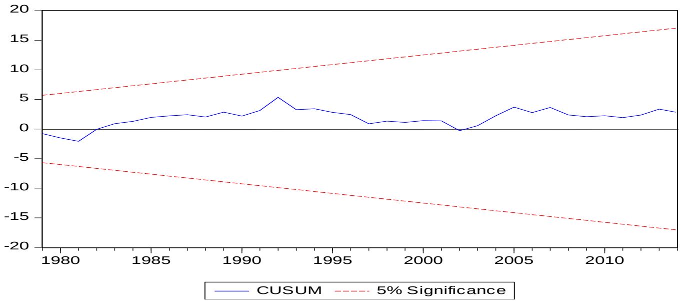
iii. Stability Analysis

Finally, we check the parameter stability of ECM model. In doing so, we apply the CUSUM and CUSUMSQ tests proposed by Brown, *at el.* (1975). We applied both test on the residuals of all three models. More specifically, the CUSUM test utilizes the cumulative sum of residuals. The plots for CUSUM and CUSUMSQ tests are presented in Figures 1, 2 and 3.

The estimated coefficients of a model are said to be stable if the CUSUM and CUSUMSQ line lies within two critical lines drawn at 5% level of significance. We do not reject the null hypothesis of ECM parameter stability, i.e., all parameters of ECM model(s) are stable at 5% level of significance if the estimated CUSUM line falls within the two bound drawn at 5% level of significance otherwise, we reject the null hypothesis. Same procedure is applied to CUSUMSQ which is based on square of recursive residuals.

The CUSUM and CUSUMSQ plots for all three models presented below specify that the coefficients of ECM models are stable as the estimated CUSUM and CUSUMSQ line lies with two critical boundaries. Thus, we can conclude that the coefficients of estimated ECM models are stable.

Figure 1. CUSUM and CUSUMSQ Plots for model 1



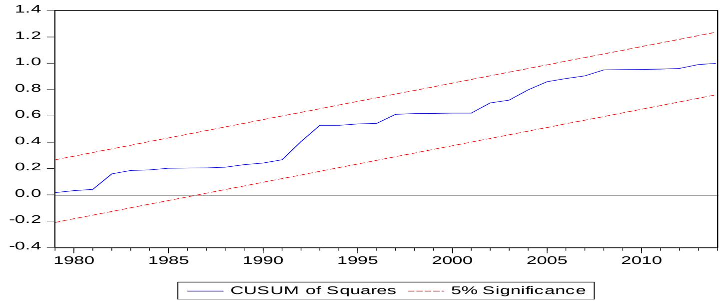
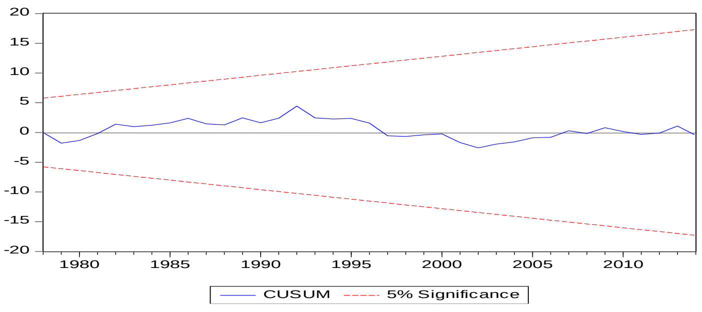


Figure 2. CUSUM and CUSUMSQ Plots for model 2



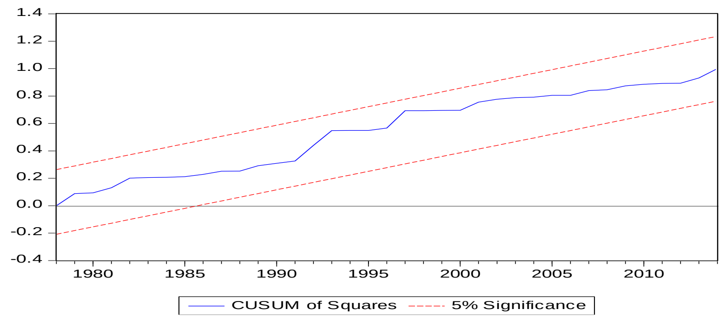
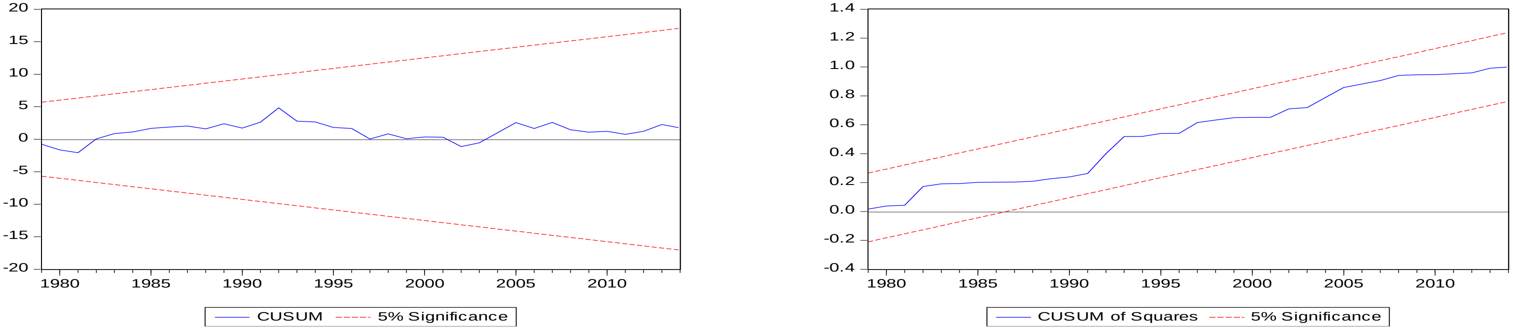


Figure 3. CUSUM and CUSUMSQ Plots for model 3



4. CONCLUSION AND POLICY IMPLICATIONS

a. Conclusion

The empirical findings of the study show that human capital, R&D expenditures and imports of machinery & equipment are crucial determinants of the TFP growth. The effects of human capital and R&D (i.e., internal technology building capabilities (technology development)) on the TFP growth are positive.

Moreover, the direct impact of the imports of machinery and equipment (i.e., embodied technology) on the TFP growth is positive and statistically significant. While, the effect of royalties and licenses fee payments (i.e., disembodied technology) is positive but statistically insignificant. In contrast to embodied and disembodied technology imports, the effect of FDI is negative, which indicates the deficiency of basic and relevant skills to absorb the technology originating from FDI. The negative relationship between FDI and the TFP growth can alternatively be explained with the lack of such type of technology transfer that enhances skills. It may thus be concluded that the trade-related technology transfer activities in the form of machinery and equipment imports enhances the TFP growth, while in the form of royalty and license fee payments abroad and FDI, respectively, weakly and negatively affect the TFP growth.

The study also lends support to the foreign technology absorption capabilities (technology deployment), that is, there is positive interactive effects of machinery and equipment imports, royalty and license payments, FDI, human capital and R&D on the TFP growth. Moreover, the combined impact of the imports of machinery and equipment and human capital as well as R&D boost the TFP growth. Furthermore, the impact of royalty and license fee payments in the presence of human capital have a positive but statistically insignificant effect on the growth of TFP. The impact of FDI combined with human capital on the growth of TFP is positive. This signifies the role of human capital in the presence of FDI linked with the TFP growth. This finding indeed verifies the acceptance of foreign technology absorption capabilities.

Having said above, we get confidence about the above reported conclusion from the results of ARDL and Error Correction models, which show that a stable long-run relationship exists between the chosen variables and that the models are robust.

b. Policy Implications

Keeping in view the above conclusion, the following policy implications may be derived to improve the TFP growth in Pakistan.

- To enhance internal technology building capabilities in the country, there is a need to raise expenditure on education and R&D, which should promote innovation activities in order to enhance the growth in TFP.
- The use of modern machinery and equipment both in embodied and disembodied form enables the economy to realize benefits from the foreign matured technology.
- Moreover, the enhancement in level and quality of basic skills is needed to benefit from FDI-linked technology transfer. Moreover, there should be sufficient investment in human capital particularly in backward regions of the economy to avail more benefits from FDI-linked project.

All these measures are expected to enhance foreign technology absorption capabilities and increase TFP growth in the economy.

APPENDIX

Empirical Estimation

i. Model 1

The results presented in Table 4 in Appendix 2 can be written in form of equation for further analysis. We first analyze model-1.

$$\Delta TFP_i = -0.1354 - 0.016137\, D\_SBREAK1971 - 0.443106\, \Delta TFP_{t-1} - 0.116861\, \Delta TFP_{t-2} + 0.092083\, \Delta lnHc_t + 0.007544\, \Delta lnHc_{t-1} + 0.011092\, \Delta lnRD_t - 0.010186\, \Delta lnRD_{t-1} + 0.005337\, \Delta lnIME_{t-1} + 0.011287\, \Delta lnRLF_t - 0.002942\, \Delta lnFDI_t - 0.001304\, \Delta(lnHC^{*}lnIME)_{t-1} - 0.004953\, \Delta(lnRD^{*}lnIME)_t + 0.01117\, \Delta(lnRD^{*}lnIME)_{t-1} + 0.008684\, \Delta(lnHC^{*}lnFDI)_t - 0.440528\, TFP_{t-1} + 0.10446\, lnHc_{t-1} + 0.028704\, lnRD_{t-1} + 0.017701\, lnIME_{t-1} + 0.001238\, lnRLF_{t-1} - 0.00807\, lnFDI_{t-1} + 0.004266\, (lnHC^{*}lnIME)_{t-1} + 0.039998\, (lnRD^{*}lnIME)_{t-1} + 0.001289\, (lnHC^{*}lnFDI)_{t-1} \quad \ldots (1)$$

The equation above can be used to obtain long-run estimates as it is $IIDN(0, \delta^2)$. Long-run parameters can be obtain assuming steady state condition which normalize the equation, i.e., ΔTFP = 0, which means $\Delta TFP = TFP_t - TFP_{t-1} = 0 \Rightarrow TFP_t = TFP_{t-1}$. All the differenced variables will disappear through application of above condition and in this way we obtain long-run estimates.

$$0 = -0.440528\, TFP_t + 0.10446\, lnHc_t + 0.028704\, lnRD_t + 0.017701\, lnIME_t + 0.001238\, lnRLF_t - 0.00807\, lnFDI_t + 0.004266\, (lnHC^{*}lnIME)_t + 0.039998\, (lnRD^{*}lnIME)_t + 0.001289\, (lnHC^{*}lnFDI)_t \quad \ldots (2)$$

By rearranging Equ.2 we get,

$$0.440528\, TFP_t = 0.10446\, lnHc_t + 0.028704\, lnRD_t + 0.017701\, lnIME_t + 0.001238\, lnRLF_t - 0.00807\, lnFDI_t + 0.004266\, (lnHC^{*}lnIME)_t + 0.039998\, (lnRD^{*}lnIME)_t + 0.001289\, (lnHC^{*}lnFDI)_t \quad \ldots (3)$$

Dividing both sides by the coefficients of TFP we obtain,

$$TFP_t = 0.237\, Hc_t + 0.065\, RD_t + 0.040\, IME_t + 0.003\, RLF_t - 0.018\, FDI_t + 0.010\, (HC^{*}IME)_t + 0.091\, (RD^{*}IME)_t + 0.003\, (HC^{*}FDI)_t \quad \ldots (4)$$

Equ. 5 represents long-run estimated considering model 1. Similarly, we can obtain long-run parameters for models 2 and 3.

REFERENCES

Adil, I.H. (2012) Robust Outlier Detection Techniques for Skewed Distributions and Applications to Real Data (Doctoral dissertation, International Islamic University, Islamabad). Available at: http://prr.hec.gov.pk/Thesis/1542S.pdf

Atique, Z., M.H. Ahmad, U. Azhar, and A.H. Khan (2004) The Impact of FDI on Economic Growth under Foreign Trade Regimes: A Case Study of Pakistan [with Comments]. *The Pakistan Development Review*, 43:4, 707-718.

Benhabib, J. and M.M. Spiegel (1994) The Role of Human Capital in Economic Development Evidence from Aggregate Cross-Country Data. *Journal of Monetary Economics*, 34:2, 143-173.

Blomstrom, M., R.E. Lipsey, and M. Zejan (1994) What Explains the Growth of Developing Countries? *Convergence of productivity: Cross-national studies and historical evidence*, 243-59.

Borensztein, E., J. De Gregorio, and J. W. Lee (1998) How Does Foreign Direct Investment Affect Economic Growth? *Journal of International Economics*, 45:1, 115-135.

Brown, R.L., J. Durbin, and J.M. Evans (1975) Techniques for Testing the Constancy of Regression Relations Over Time, *Journal of the Royal Statistical Society*, Series B, 37, 149-192.

Carkovic, M.V. and R. Levine (2002) Does Foreign Direct Investment Accelerate Economic Growth? *University of Minnesota Department of Finance Working Paper*.

Coe, D. T. and E. Helpman (1995) International R&D Spillovers. *European Economic Review*, 39:5, 859-887.

Coe, D.T., E. Helpman, and A.W. Hoffmaister (1997) North and South Spillovers. *Economic Journal* 107, 134–149.

Falki, N. (2009) Impact of Foreign Direct Investment on Economic Growth in Pakistan. *International Review of Business Research Papers*, 5:5, 110-120.

Girma, S. (2005) Absorptive Capacity and Productivity Spillovers from FDI: A threshold regression analysis. *Oxford Bulletin of Economics and Statistics*, 67:3, 281-306.

Hall, R.E. and C.I. Jones (1999) Why Do Some Countries Produce So Much More Output per Worker than Others? (No. w6564). *National Bureau of Economic Research*, *Washington, D.C.*

Hamid, A. and J.H. Pichler (2009) Human Capital Spillovers, Productivity and Growth in the Manufacturing Sector of Pakistan. *The Pakistan Development Review*, 125-140.

Hermes, N. and R. Lensink (2003) Foreign Direct Investment, Financial Development and Economic Growth. *The Journal of Development Studies*, 40:1, 142-163.

Huq, M. (2006) Building Technological Capability in Developing Countries: The Case for a Technology Policy.

IMF (various issues) *Balance of Payments Statistics yearbook.* International Monetary Fund, Washington, D.C.

ILO (2013) LABORSTA Labour Statistics Database, Geneva: International Labour Office.

Irfan, M. (2009) Pakistan’s Wage Structure, during 1990-91–2006-07 (No. 2009: 54). Pakistan Institute of Development Economics.

Kemal, A. R. and S. I. Ahmed (1992). Report of the Sub-Committee on Sources of Growth in Pakistan. Islamabad: Pakistan Institute of Development Economics.

Khan, S. (2006) Macro Determinants of Total Factor Productivity in Pakistan. *Working Paper Series No. 10*, *State Bank of Pakistan, Karachi.*

Khan, M.A. (2007) Foreign direct Investment and Economic Growth: The Role of Domestic Financial Sector (No. 2007: 18). Pakistan Institute of Development Economics.

Mahmood, Z. and R. Siddiqui (2000) State of Technology and Productivity in Pakistan's Manufacturing Industries: Some Strategic Directions to Build Technological Competence. *The Pakistan Development Review*, 39:1,1-21.

Mayer, J. (2001) Technology Diffusion, Human Capital and Economic Growth in Developing Countries. United Nations Conference on Trade and Development.

Mendi, P. (2007) Trade in Disembodied Technology and Total Factor Productivity in OECD Countries. *Research Policy*, 36:1, 121-133.

Mowery, D. C. and J. E. Oxley (1995) Inward Technology Transfer and Competitiveness: The Role of National Innovation Systems. *Cambridge Journal of Economics*, 19:1, 67-93.

Pasha, H.A., A. G. Pasha, and K. Hyder (2002) The Slow Down of the Growth of Total Factor Productivity in Pakistan. Social Policy and Development Centre (SPDC), Karachi, Pakistan, Research Report No. 44.

PCST (various issues) *Scientific and Technological Indicators of Pakistan.* Islamabad: Pakistan Council for Science and Technology (PCST), Ministry of Science and Technology.

PCST (2014) S*cience, Technology and Innovation Indicators of Pakistan.* Islamabad: Pakistan Council for Science and Technology (PCST), Ministry of Science and Technology.

GOP (1994) *Labour Force Survey* (Various Issues). Federal Bureau of Statistics, Islamabad.

GOP (Various Issues) *Pakistan Economic Survey*. Ministry of Finance, Economic Adviser's Wing, Islamabad.

Pesaran, M.H., Y. Shin, and R.J. Smith (2001) Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics*, 16, 289-326.

Radhu, G.M. (1973) Transfer of Technical Know-how through Multinational Corporations in Pakistan. *The Pakistan Development Review*, 361-374.

Romer, P. (1990) Endogenous Technological Change. *Journal of Political Economy,* 98, S71–S102.

SBP (2010) *Handbook of Statistics on Pakistan Economy 2010.* State Bank of Pakistan, Karachi.

Teixeira, A.A. and N. Fortuna (2010) Human capital, R&D, Trade, and Long-run Productivity. Testing the Technological Absorption Hypothesis for the Portuguese Economy, 1960–2001. *Research Policy*, 39:3, 335-350.

Tufail, M., and A.M. Ahmed (2015) Measuring Total Factor Productivity and Finding the Determinants of Total Factor Productivity at Sectoral Level: A Case Study of Pakistan. *Industrial Engineering Letters*, 5:6, 38-53.

Wang, J.Y. and M. Blomström (1992) Foreign Investment and Technology Transfer: A Simple Model. *European Economic Review*, 36:1, 137-155.

Wang, C. and L. Yu (2007) Do Spillover Benefits Grow with Rising Foreign Direct Investment? An Empirical Examination of the Case of China. *Applied Economics*, 39:3, 397-405.

World Bank (2014) World Development Indicators (Washington D.C.: The World Bank).

Xu, B. and J. Wang (2000) Trade, FDI, and International Technology Diffusion. *Journal of Economic Integration*, 15:4, 585-601.

Xu, B. and E. P. Chiang (2005) Trade, Patents and International Technology Diffusion. *The Journal of International Trade & Economic Development*, 14:1, 115-135.