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Technological Spillovers, Manufacturing Growth and Transboundary Pollution in Case of Pakistan

Muhammad Usman[1], Gulnaz Hameed[2*], Abdul Saboor[3] and Khuram Nawaz Sadozai[4]

[1] PhD scholar at PMSA-Arid Agriculture University Rawalpindi.
[2] Assistant Professor at PMSA-Arid Agriculture University Rawalpindi
[3] Professor at PMSA-Arid Agriculture University Rawalpindi
[4] Assistant Professor, Department of Agricultural & Applied Economics, The University of Agriculture, Peshawar.

ABSTRACT

Role of technological spillover in manufacturing sector growth and climate change is the running debate in the world to avoid the problem of production inefficiency and environmental damages. Environment friendly technological spillover plays pivotal role in manufacturing sector growth which leads to economic growth. In order to investigate the inconclusiveness of the major issues of production inefficiency and climate change in Pakistan the current research was aimed at finding the relationship between technological spillovers, manufacturing growth and climate change. To meet the objectives, the study investigated both short run and long run dynamics by employing Autoregressive Distributive Lagged (ARDL) model. An annual time series data over the period of 1973 to 2017 was collected for comparative analysis of technological spillover performance in manufacturing sector and environmental condition of the country. The results of CUSM test and Bound test validated the existence of long run co-integration relationship among estimated models. The results demonstrated that technological spillover performs significantly positive role in manufacturing growth with less absorptive ability. The empirical analysis proved that technological spillover and imported technology have affirmative role in reducing amount of net Carbon emission over the long run. It is suggested that the firms should adopt innovative technologies and try to improve absorptive capacity while government must opt country specific policies to control negative externalities.

Keywords

Technology Spillover, Absorptive Capacity, Manufacturing Growth, Time Series Empirics

JEL Classification

N7, O31, F18

* Corresponding author: gulnaz.hameed@uaar.edu.pk

1. Introduction

Technological spillover has performed straightforward functioning in manufacturing growth, environmental performance in both developed and developing countries (Coe, Helpman, & Hoffmaister, 2009; Di Maria & Smulders, 2017; Z. Liu et al., 2015). Technological spillover execute central role in industrial productivity, new innovation, learning by doing and value addition of manufacturing sector. It is destroying environment severely in developing countries due to large population and lack of precautionary measures adopted for imported technology. However, international trade plays positive role in knowledge spillover, new innovation and introduces efficient product varieties across the region. International trade in technological products increases the market size through innovative commodity varieties. Trade openness plays a fundamental role for introducing new varieties as it provides ways to access technical knowledge which subsequently reduces the cost of innovation (Coe & Helpman, 1995).

The innovative technology provides more efficient products with less negative externalities. The firm expenditure on Research and Development (R&D) spillover and firm's own innovation perform vital role to reduce the emission of CO_2 in the environment. The R&D spillover has both direct (improved output performance) and indirect (reduced carbon emission) impacts on industrial performance (Jiao, Yang, & Bai, 2018; Lee, 2013). Currently, global warming and climate change is attaining more attention to reduce net CO_2 emission and clean environment to save the ozone layer. So, initiative of ISO-9001 certification for quality control accomplish positive role in reduction of negative externalities, innovation and producing market compatible products which attain through domestic and foreign R&D spillovers (Alemdar & Özyildirim, 2002; Bittencourt & Giglio, 2013; Mayer, 2000).

In addition, an open economy extracts larger productivity benefits from foreign R&D expenditure than less open economies through trade liberalization (Coe & Helpman, 1995; Coe et al., 2009). The knowledge based technological spillover performs fundamental role in output performance of host country. However, developing countries can enhance their production through investing in R&D spillover. The technology imports from developed to developing countries not only results in increased productivity but it also improves education level and innovative thinking of host country's labor force (Mingyong, Shuijun, & Qun, 2006; Seck, 2012). Furthermore, countries' disbursements on human capital to learn new knowledge directly improve the education, skill and learning by doing process which leads to raise in output productivity (Mayer, 2000).

The empirical results of Dalgıç & Mıhç, 2013; Gorkey-Aydinoglu suggested that contribution of R&D spillover by the means of foreign technology and domestic innovation has significant impact on economic growth. In addition, imported technology creates externalities which may be positive or negative. The technology externalities include the technological transformation and production of CO_2 emission, manufacturing wastes, and other harmful gases which affect the climate factors. But technology spillover with less negative externalities is more valuable and socially optimal. Similarly, Youssef, 2009 argued that increase in R&D spillover lead to positive externalities and increased production while reduced the pollution thus raised the society's welfare. W. Liu, Xu, Yang, Zhao, & Xing, 2016 highlighted through empirical analysis that technological spillover affected the manufacturing output positively with innovative knowledge creation. In short term it also produces negative externalities (like, CO_2 emission which damages the environmental very poorly). The pollution spillover has negative impact on Total Factor Productivity (TFP) growth with larger magnitude of country's own emission control. The rise in pollution is harmful for TFP growth in both developed and developing countries (Costantini, Mazzanti, & Montini, 2013; Empora, 2017).

New technological innovation and new product varieties lead to unique product to get high market share (W. Liu et al., 2016). Abatement cost will fall as a result of successful R&D activities and alternative use of knowledge spillover (Heal & Tarui, 2010). Other pioneer studies including that of Dalgıç & Mıhç, 2013; Türker, 2012; Vayá, López-Bazo, Moreno, & Suriñach, 2004 argued that R&D spillover and innovation capacity of host country is dependent on innovative thinking and absorptive ability. A strategic partnership is required between research institute and domestic firms which increases the system of innovative thinking and technology improvement. The firm gain profit on the basis of unique product in competitive market, this strategy increased customer satisfaction, performance and comparative advantage on other firms (Seck, 2012; Zarrabi & Vahedi, 2012) .

The scientific literature shows that in the upcoming decade high temperature and change in climate is burning issue for developing countries, so high temperature and climate change carrying significant increase in amount of hydro events and bring extreme changes in temperature in current century. The average global temperature from last century has accelerated by 0.8 C^o, whereas changes in precipitations is reducing over the time. Currently, global issues are arising such as climate change, deforestation, global warming, depletion of ozone layer, and biodiversity preservation. Such issues cause environmental damages and create serious problems for future (Fischer, 2008; Lei, Shangguan, & Rui, 2012; Z. Liu et al., 2015).

In case of Pakistan both industrial and services sector has more Foreign Direct Investment (FDI) with higher labor productivity share while agriculture sector presenting poor condition of FDI inflow with low labor force productivity. Mohammadi, Veismoradi, Hashemi, Akbari, & Rostami, 2015; Serfraz, 2017 found that agriculture sector requires more technology for increasing potential level of output to attain the fruit from R&D spillovers. Mehmood, Chaudhry, Tufail, & Irfan, 2009 highlighted the probability of new technology adoption in large scale manufacturing in Pakistan and suggested that new technology adoption depends on the size and volume of sale, type of ownership, geographical and environmental condition. Kuo & Young, 2008 concluded that FDI increases the technology spillover by increasing carbon emission in host country. Pakistan textile manufacturing industry produces wastewater which is not only demolishing the environment but also reduces the output productivity of textile industry. The treatment of textile wastewater is costly process which generates long lasting effects on climate factors (Verma, Dash, & Bhunia, 2012).

Technological spillover in manufacturing sector produces harmful, waste water, smoke, and other waste material which produce direct impact on climate change. In Pakistan, the research activities and research expenditure were increasing over the last two decades (Mehmood et al., 2009). Every research activity has positive outcome but unfortunately such research activities are not contributing for economic development of the country. Research activities have been promoted but innovative ideas could not further proceed to be implemented for economic development. With the advent of endogenous growth theory, a large segment of economic literature has an eternizing interest in the relationship between R&D spillovers and role of absorptive ability to enhance the long term economic growth (Kazmi, 2016; Kinda, 2012; Mustafa, 2011).

Like other developing countries, Pakistan's technological knowledge mostly depends on knowledge spillover produced in developed countries (Kazmi, 2016; Mehmood et al., 2009). So there is a dire need to answer the questions like how the technology spillover contributes in the manufacturing growth? Does the manufacturing sector labor force is efficient to absorb the spillover technology? Does technological spillover raise environmental pollution in the country? How trade liberalization contributes in the economic growth via R&D spillovers in Pakistan? What is the role of technological spillover in manufacturing sector in view of aspects like production efficiency, productivity growth, absorptive capacity of industrial labor, environmental pollution produced by industrial sector, and importance of ISO-9001 certification in pollution reduction?

To address the above questions the specific objectives of current study are; to examine the role of technological spillover in manufacturing sector growth/output performance through technology diffusion in Pakistan, to investigate the absorptive ability of new knowledge spillover in Pakistani work force in manufacturing sector, to explore specific foreign R&D channel suitable for manufacturing growth, to estimate the transboundary pollution in Pakistan and role of technology spillover in climate change and CO_2 emission.

2. Research Methods

2.1 Theoretical Background

The numerous channels and ways were explored in voluminous stream of research to investigate the national and international technology spillovers impact on country industrial productivity. Like Globalization, Foreign Direct Investment (FDI), cross country, regional and sectoral technology spillovers effects, knowledge sharing interactions among countries, multinational presence, The Coe & Helpman, 1995 seminal work explore empirically the contribution of R&D spillovers to country's TFP level. The imports of intermediate goods (machinery and equipment's) are the main channel of technology spillovers.

"Technology consists of a set of processes like how to produce, how to use the tools/equipment's and experiments that are used to produce the goods and services and how to transfer information from internal and external resources to provide innovative ways for input output process?" (Gujarati & Dawn, 2010). In development, innovative technology with efficient utilization of the human capital perform key role to absorb and develop new ways of production. Human capital comprises of human resources, education, skillful creative and innovative labor, which majorly contribute in development of technology. "In an environment of uncertainty, innovation capacity developed through knowledge transfer, and the macro-level growth models, has emphasized the role of science and technology models" (Romer, 1990).

The Environmental Kuznets Curve (EKC) shows the postulated connection between environment quality, innovative technology and economic development i.e. high per capita income (Hanley, 2001; Hanley, Shogren, & White, 2016; Stern, 2004). The EKC monotonically showed raise in emissions which is evident to decrease the income in long term. According to Stern (2004), review of both the theoretical and empirical work on the EKC leads to be skeptical about the existence of a simple and predictable relationship between pollution and per capita income. The higher level of income and sustained environment can be achieved through innovation and adoption of new knowledge spillover. However, the emission reduces the technological innovation which declines the income not only in developing but also in developed countries(Stern, 2004; Torras & Boyce, 1998). In contrast, the innovative technological spillover is helpful in reduction of pollution emission. The important point is why markets and manufacturing sector fails to allocate the resources? The reason behind is negative externalities(Hanley et al., 2016). Hanley, 2001 argued that analysis of environmental issues in terms of externalities shows fails in the resource allocation. Currently, the phenomena of "investment in green technology" is workable which can boost the firm productivity, capacity to get competitive advantages and measures for pollution reduction (Galdeano-Gómez, Cespedes-Lorente, & Martínez-del-Río, 2008).

2.2 Data and Data Sources

The time series empirics are based on R&D spillover models concentrate on manufacturing sector's productivity and environmental factor (Coe et al., 2009; S. Wang, 2015; X. Wang, Fang, Zhang, & Fang, 2018). In order to examine the role of technological spillover through different aspects of manufacturing sector of Pakistan, the manufacturing sector productivity and net Carbon emission are taken as dependent variables in two different models while net Foreign Direct Investment (FDI_t), technological imports ($TECH_t$), Trade Openness (TO_t) as main dependent variables. However, human capital (HC_t), labor force in industrial sector (LF_t), are taken as control variables in both models, in addition to capture the absorptive ability of foreign knowledge, interactive term of human capital with foreign direct investment ($HC*FDI_t$).

For empirical outcome, the time series annual data for the period of 1973 to 2017 was gathered from various sources. Data relevant to Pakistan technological spillover, manufacturing sector performance and climate change is collected from the various issues of Pakistan Economic Survey, Federal Bureau of Pakistan, Ministry of Finance Pakistan, Hand book of Statistics of Pakistan's Economy 2015 published by State Bank of Pakistan, Penn World table 9.1 and World Bank, and World Development Indicators (WDI).

2.3 Empirical Framework

Considering the technological augmented model and knowledge spillover as endogenously determined, the level of technology spillover is dependent on both domestic and foreign R&D variables (Coe et al., 2009; Mohammadi et al., 2015). Hence, the equation for technological level can be written as;

$$A_t = DRD_t^{\alpha_1}, FRD_t^{\alpha_2} \tag{1}$$

Here the A_t is Total Factor Productivity (TFP), DRD_t is domestic R&D while FRD_t is foreign R&D. Taking log and add intercept in equation 1 follows as,

$$lnA_t = \alpha_0 + \alpha_1 DRD_t + \alpha_2 FRD_t \tag{2}$$

Where, DRD_t representing the domestic R&D variables and FRD_t representing foreign R&D variables affects the technological spillover effect on economic growth and absorptive capacity. The study took the intensive form of Hicks Neutral, (Dupuy, 2006) whereas growth per unit of effective labor($y_t = {}^{Y_t}/_{L_t}$), technology per unit of effective labor ($A_t = {}^{A_t}/_{L_t}$) and capital per unit of effective labor ($k_t = {}^{K_t}/_{L_t}$) are given in equations 3.

$$y_t = A_t k_t^{\beta} \tag{3}$$

Taking log the equation (3) takes the following form

$$lny_t = lnA_t + \beta lnk_t \quad (4)$$

Putting value of lnA_t from equation (2)

$$lny_t = \alpha_0 + \alpha_1 lnDRD_t + \alpha_2 lnFRD_t + \beta lnk_t \quad (5)$$

In equation 5, y_t is productivity output in manufacturing sector, while domestic RD_t^d variables and foreign RD_t^f variables are presented in weighted. The weighted FRD_t stock is proxy of technological spillover in manufacturing sector (Dalgic and Michi, 2013) in this regard weighted stock of both domestic and foreign R&D coefficients demonstrate the technological spillover in industrial sector. In the single stage estimation, by including the technological spillover as well as absorptive capacity series of variables, the nonlinear estimation equation become,

$$lny_t = \alpha_0 + \alpha_1 lnTS_t + \alpha_2 (X_t) + HC * lnTS_t + \varepsilon_t \quad (6)$$

For empirical analysis manufacturing value addition annual growth and net carbon emission are taken as dependent variables in two different models. The study estimated model 2.6 by adopting the foreign RD spillover indicators. Empirical outcomes of OLS based Autoregressive Distributive Lag (ARDL) model of conditional unrestricted error correction approach is applied for long run cointegration association which was develop by (M Hashem Pesaran, Shin, & Smith, 1996). To investigate the long as well as short run appearance of variables under consecration the ARDL technique is applied which provides the parametric stability through Cumulative Sum (CUSUM), and Cumulative Sum of Square (CUSUMQ) tests. For accomplishment of long run and short run dynamics, the Bound test show the existence of long run relationship and Error Correction Model (ECM) coefficient determines the short run equilibrium and time for convergence to stability position.

In Vector Error Correction (VAR) approach the lag structure remains same for concerning variables while ARDL technique provide way to select optimal and different lags of each variable. The ARDL estimate used the following equation for parametric action:

$$\Delta\ln(\mathrm{Manu})_t = \beta_0 + \sum_{t=1}^{n}\beta_1\Delta\ln(\mathrm{Manu})_{t-1} + \sum_{t=1}^{n}\beta_2\Delta\ln(\mathrm{FDI})_{t-1} + \sum_{t=1}^{n}\beta_3\Delta\ln(\mathrm{TECH})_{t-1} + \sum_{t=1}^{n}\beta_4\Delta\ln(\mathrm{TO})_{t-1} + \sum_{t=1}^{n}\beta_5\Delta\ln(\mathrm{LF})_{t-1} \sum_{t=1}^{n}\beta_6\Delta\ln(\mathrm{HC})_{t-1} + \sum_{t=1}^{n}\beta_7\Delta\ln(\mathrm{HC}\times\mathrm{FDI})_{t-1} + \delta_1\ln(\mathrm{Manu})_{t-1} + \delta_2\ln(\mathrm{FDI})_{t-1} + \delta_3\ln(\mathrm{TECH})_{t-1} + \delta_4\ln(\mathrm{TO})_{t-1} + \delta_5\ln(\mathrm{HC})_{t-1} + \delta_6\ln(\mathrm{LF})_{t-1} + \delta_7\ln(\mathrm{HC} * \mathrm{FDI})_{t-1} + \varepsilon_t \quad (7)$$

The equation given above is representation of short run dynamics of ARDL model whereas $\beta_0, \beta_1, \dots\dots\dots\dots \beta_7$, are short run parameters, (the variable in change (Δ) form are short run parameters) while parameters $\delta_1,\ \delta_2, \dots\dots\dots\dots\dots \delta_7$ represent long term association and ε_t represent the error term in the model. In equation 7, the dependent variable is manufacturing section value addition ($Manu_t$) while explanatory variables are net Foreign Direct Investment (FDI_t), technological imports ($TECH_t$), Trade Openness (TO_t) as main dependent variables. However, human capital (HC_t), labor force in industrial sector (LF_t), are taken as control variables in both models, in addition to capture the absorptive ability of foreign knowledge, we used interactive term of human capital with foreign direct investment ($HC*FDI_t$)

The estimated equation for impact of technology spillover on environmental performance is given below. In equation 8 the independent variables are same as equation 7 while dependent variable is CO_2 emission produced by manufacturing sector in Pakistan.

$$\Delta\ln(CO_2)_t = \beta_0 + \sum_{t=1}^{n}\beta_1\Delta\ln(Manu)_{t-1} + \sum_{t=1}^{n}\beta_2\Delta\ln(FDI)_{t-1} + \sum_{t=1}^{n}\beta_3\Delta\ln(TECH)_{t-1} + \sum_{t=1}^{n}\beta_4\Delta\ln(TO)_{t-1} + \sum_{t=1}^{n}\beta_5\Delta\ln(LF)_{t-1}\sum_{t=1}^{n}\beta_6\Delta\ln(HC)_{t-1} + \sum_{t=1}^{n}\beta_7\Delta\ln(HC\times FDI)_{t-1} + \delta_1\ln(Manu)_{t-1} + \delta_2\ln(FDI)_{t-1} + \delta_3\ln(TECH)_{t-1} + \delta_4\ln(TO)_{t-1} + \delta_5\ln(HC)_{t-1} + \delta_6\ln(LF)_{t-1} + \delta_7\ln(HC * FDI)_{t-1} + \mu_t \quad (8)$$

Here μ_t represent the error term in the model.

3. Results and Discussion

Before carrying out a formal analysis, to determine the existence of long run relationship among the considered variables, conventional unit root test namely Augmented Dickey Fuller (ADF) was applied.

3.1 Unit Root Test

Results of the unit root test are given in Table 1. Time series empirics are highly dependent on Cointegration relationship but it is mandatory to investigate the order of integration of given variables before final estimation method for co-integration relation to avoid the problem of spurious results. The ADF test describes the behavior of given variables and report that given variables can be used in ARDL or not. The findings of ADF test are given table 3.1 which shows that all the given variables are integrated at level or first difference (I (0) or I (1)), so ARDL method of cointegration is applicable for final empirical outcomes.

Table 1: Result of Unit Root Test

Variables	Level	1stDifference
$MANU_t$	-1.179	-6.229
	(0.9015)	(0.0000)**
$CO2_t$	-1.760	-5.068
	(0.5250)	(0.0009)**
FDI_t	-2.352	-4.306
	(0.0197)*	(0.0001)
LF_t	-1.300	-6.937
	(0.8746)	(0.0000)**
$TECH_t$	-1.071	-4.011
	(0.7045)	(0.0411)**
TO_t	-1.013	-6.028
	(0.9316)	(0.0001)**
HC_t	-1.939	-6.465
	(0.6169)	(0.0000)**

*, ** shows the stationary of given variables at level and first difference correspondingly
Source: Authors' own estimation.

The optimal lag selection is important for ARDL analysis after detecting stationarity of variables. The AIC is not as consistent but is usually more efficient, while SBC is usually more consistent but inefficient (Brooks, 2008). For final analysis, 4 lags are selected on the bases of the Akaike Information Criterion (AIC), and Hannan- Quinn Criterion (HQC). The output results are shown in table 2.

Table 2: VAR base Optimal Lag Selection Criterion

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-66.94312	NA	9.51e-08	3.697156	3.992710	3.804019
1	187.2325	406.6810	3.46e-12	-6.561626	-4.197194*	-5.706722
2	239.9014	65.83612	3.63e-12	-6.745070	-2.311762	-5.142126
3	293.4926	48.23204	5.75e-12	-6.974628	-0.472442	-4.623643
4	415.6222	67.17127*	8.51e-13*	-10.63111*	-2.060045	-7.532082*

*Shows the optimal lag length for ARDL Bound test.

Source: Authors' own estimation.

3.2 Technology Spillover role in Manufacturing growth and Absorptive Ability

This section attempts to accomplish the precise objectives of the study like technology spillover role in manufacturing growth, testing the absorptive ability of manufacturing labor force and highlights the suitable channel for technology spillover in manufacturing sector. The result of ADRL bound test is given in table 3, the null hypothesis of Bound test is “no long run relationship exist”. On the basis of F-stat calculated value, the null hypothesis is rejected because F-test value fall in rejection rejoin, which is higher than upper bounds critical values. In addition, the result shows the existence of long run Cointegration relationship among variables under consideration.

Table 3: ARDL Bound Test Results

Null Hypothesis: No long-run relationships exist		
Test Statistic	Value	K
F-statistic	8.069472	6
	Critical Value Bounds	
Significance	I0 Bound	I1 Bound
10%	1.75	2.87
5%	2.04	3.24
2.5%	2.32	3.59
1%	2.66	4.05

Source: Authors' own estimation.

The results of long run relationship among technological spillover and manufacturing growth are given in table 4. In this model, foreign direct investment (FDI_t), technological imports ($TECH_t$) and trade openness (TO_t) are three proxies to capture the technological spillover. The results of foreign direct investment, trade openness, and technology imports are statistically significant with positive sign. So, increase in technological spillover from foreign source leads to raise the manufacturing growth over the long run. The coefficient of foreign direct investment (FDI_t) has significantly positive impact on manufacturing sector productivity both in short as well as in long run dynamics with long run elasticity value 0.23. In similar line, Trade Openness (TO_t) and technological imports ($TECH_t$) perform significantly positive impact on economic growth in long run with elasticity value 1.46 and 0.15 respectively. The Trade Openness does not exert any significant impact in short run with contradiction of technological imports. The lag coefficient of manufacturing lector growth has positively significant impact on manufacturing growth which shows technology upgrading is important with previous technology (old technology). The results of the study are consistent with the findings of Liu et al. (2016).

However, the findings of industrial labor force, and interactive term is significantly negative. The possible justification is that the technology imported from developed countries cannot be absorbed efficiently. The findings of labor productivity in manufacturing sector are consistent with the findings of Kuo & Young, 2008. Labor force working in manufacturing is mostly illiterate, less skilled and inexperienced, so labor force is not capable to absorb the imported technology. So, the interactive term result shows that learning through technological spillover cannot perform significant role to absorption of external knowledge spillover, to enhance internal innovation and innovative thinking the absorptive ability matter (Bittencourt & Giglio, 2013). Research and development spillover perform crucial role to innovate and increase the capability of "learning by doing" and "learning through training" (Pavitt, 1984). The coefficient of human capital has positively significant impact on output performance. This shows that investment on education and pays high return on that education. The behavior of estimated coefficients are consistent with the findings of Kuo & Young, 2008; Mingyong et al., 2006; Seck, 2012 as more open economies extract larger productivity benefits from foreign R&D expenditure than less open economies.

In short run, FDI_t, $TECH_t$ insert significantly positive impact on manufacturing growth while TO_t, LF_t, HC_t, have no significant impact on manufacturing growth. In short run, interactive term $(HC*FDI)_t$ has significantly negative impact on manufacturing growth, which shows that technology imported through FDI cannot absorbed effectively. In addition, the lag coefficient of MANUF(-1) growth has significantly positive impact on current year performance with 0.35 elastic value.

The error correction mechanism ECM (-1) coefficient has significantly negative sign at 1 percent level which shows that variables in given model are cointegrated in long run. The coefficient of ECM is 1.28, which implies that deviation from steady state position in manufacturing sector in estimated model is corrected by 128 percent by the same time period (Shittu, 2012). The possible justification of the high value ECM coefficient is dependency of manufacturing sector of Pakistan which is based on imported technology, so any shock in manufacturing sector must be corrected 128 percent in same year through imported technology or FDI shocks. The ECM coefficient shows that non-adjustment in manufacturing sector takes place relatively at more quick speed of adjustment.

Table 4: Long Run and Short Run Dynamics of ARDL Model

Long Run Coefficients		Short Run Coefficients	
Variable	**Coefficient**	**Variable**	**Coefficient**
FDI_t	0.233074 (0.0001)***	**$D(FDI)_t$**	0.160608 (0.0923)*
TO_t	1.461524 (0.0000)***	**$D(TO)_t$**	0.049690 (0.8134)
$TECH_t$	0.154219 (0.0028)***	**$D(TECH)_t$**	0.032255 (0.0490)**
HC_t	1.239437 (0.0001)***	**$D(HC)_t$**	0.353613 (0.8457)
$HC*LFDI_t$	-0.583203 (0.0000)***	**$D(HC*FDI)_t$**	-0.290169 (0.0842)*
LF_t	-0.075445 (0.0205)**	**$D(LF)_t$**	-0.009229 (0.4626)
		$D(MANUF(-1))_t$	0.359062 (0.0830)*
		ECM(-1)	-1.289925 (0.0004)***

The explained variable is LManu. The variables under consideration are in logarithmic form because data of given variables are not available in same unit. So to enhance the actual outcome log of variables is used. The satiric specifying the significance level "*, **, ***" at 10, 5, and 1 percent respectively. In addition the values with parenthesis are coefficient value and values in parenthesis are probability values of t-statistic.

Source: Authors' own estimation.

The error correction model (ECM(-1)) estimated through Mohammad Hashem Pesaran & Pesaran, (1997) suggests that cumulative sum of recursive residuals CUSUM and CUSUM square tests to evaluate the parametric consistency. The estimated result of diagnostic tests is given in table 5 which shows that there is no issue of Heteroskedasticity and serial correlation in the given data set. Furthermore, the graph of CUSUM test is confirmation of existence of long run relationship among variables and estimated coefficients are structurally stability over the long run (Appendix A and B).

Table 5: Diagnostic tests results

Diagnostic Test	F-statistic
Serial Correlation	0.229679
	(0.9105)
Heteroskedasticity	0.570524
	(0.8746

Source: Author's Estimation

3.3 Technology Spillover Impact on environmental performance

In manufacturing sector, each firm sign an agreement with government for higher R&D spending and degree of net carbon emission production domestically. Technology spillover produces negative or positive externalities but social optimum instruments tell the efficient use of R&D technology and suggest the economic impact on the society. However, the CO_2 emission can be controlled effectively through R&D spillover (technological innovation) tradable permits, and taxes on carbon emission. The internal or external climate agreements relevant to R&D spillover are not synchronized according effectiveness of social cost and social benefits from climate policies. Furthermore, the government tax agreement on emission control is highly dependent on technology abetment cost and level of innovation. The results of lag selection criterion are given in table 6 which permit 4 lag to estimate the ARDL bound test.

Table 6: VAR based selected lag length criterion

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-66.94312	0	9.51e-08	3.697156	3.992710	3.804019
1	187.2325	406.6810	3.46e-12	-6.561626	-4.197194*	-5.706722
2	239.9014	65.83612	3.63e-12	-6.745070	-2.311762	-5.142126
3	293.4926	48.23204	5.75e-12	-6.974628	-0.472442	-4.623643
4	415.6222	67.17127*	8.51e-13*	-10.63111*	-2.060045	-7.532082*

Source: Authors' own estimations

ARDL Bounds Test

The results of ARDL bound test are given in table 7 which show that estimated value of F-stat is higher than upper bound and in that case null hypothesis of no long run relationship is significantly rejected. In case of technology spillover effect on CO_2 emission the rejection of null hypothesis highlights that there is long run cointegration relationship between technology imports and CO_2 emission in case of Pakistan. The ARDL estimates shows technology spillover has long term effect on environmental performance. The empirical results are fairly matching with the findings of (W. Liu et al., 2016; Z. Liu et al., 2015).

Table 7: Estimates of ARDL Bound Test

Null Hypothesis: No long-run relationships exist		
Test Statistic	Value	K
F-statistic	6.229124	6
	Critical Value Bounds	
Significance	I0 Bound	I1 Bound
10%	1.75	2.87
5%	2.04	3.24
2.5%	2.32	3.59
1%	2.66	4.05

Source: Author's Estimation

The table 8 shows the estimated results of long run and short run dynamics technology spillovers and its impact on net CO_2 emission in case of Pakistan. The estimated result shows that R&D spillovers have significantly negative impact on net CO_2 emission. Furthermore, the estimates illustrated that imported technology is helpful for net carbon emission reduction in case of Pakistan. The results show that improvement in technology and technological innovation has fundamental role in CO_2 reduction. Technological spillovers and technological advancement in Pakistan is favourable for CO_2 emission abetment over the long run. The long run coefficients of technology imports ($TECH_t$), trade openness (TO_t) and foreign direct investment inflow (FDI_t) have significantly negative. The estimates are consistent with the findings of (Alemdar & Özyildirim 2002; Jebli, & Youssef 2017; Wang, et al., 2018) the technological innovation is helpful in emission reduction and innovative technology is fundamental source to produce less emission pollution. The technology import ($TECH_t$) has less elasticity as compared to FDI_t and TO_t.

In short run both foreign direct Investment (FDI) trade openness (TO) and labor force (LF) have no significant impact on CO_2 emission while technology imports (TECH) has positive significant impact. In addition, the expenditure on education and return on education (HC) also have significantly negative impact on CO_2 production from manufacturing sector. The result shows that higher the technology imports (R&D spillover) in short run, higher the fraction of CO_2 emission (transboundary pollution) in case of Pakistan. The estimated results are justified as per findings of Jebli & Youssef, 2017; Verma et al., 2012 that technological spillover perform positive role in pollution emission.

Table 8: long run and Short run dynamic of technology spillover and CO_2 emission

Long Run Coefficients of ADRL Bound Test		Short Run Coefficients of ARDL Bound Test	
Variable	**Coefficient**	**Variable**	**Coefficient**
LFDI	-0.161805 (0.0002)***	**D(LFDI)**	0.004347 (0.6552)
LHC	.976285 (0.0011)***	**D(LHC)**	-2.204762 (0.0239)**
LTO	-0.165560 (0.6507)***	**D(LTO)**	-0.084566 (0.2773)
LTECH	-0.087630 (0.0452)***	**D(LTECH)**	0.026757 (0.0067)***
LF	0.162251 (0.0118)**	**D(LF)**	0.010012 (0.2208)
HC*LFDI	-0.340753 (0.0016)***	**D(HC*LFDI)**	0.002272 (0.8945)
		D(LCO2(-1))	-0.385935 (0.0728)
		ECM(-1)	-0.305342 (0.0101)***

The explained variable is LMANU. All variables under consideration are in logarithmic form because data of given variables are not available in same unit. The satiric indicates the significance level "*, **, ***" at 10, 5, and 1 percent respectively. In addition the values with parenthesis are coefficient value and values in parenthesis are probability values of t-statistic**.**

Source: Author's Estimation.

The results of Heteroskedasticity and autocorrelation are given in table 9. The empirics show that there is no problem of Heteroskedasticity and serial correlation in given data set.

Table 9: Diagnostic Results

Diagnostic Test	**F-statistic**
Serial Correlation	1.880957 (0.1798)
Heteroskedasticity	0.520304 (0.9281)

Source: Authors' own Estimations

4. Conclusion and Policy Recommendation

The fundamental role of technology spillover in manufacturing sector is to improve the output performance through efficient and market competitive products with positive R&D spillovers. The crucial impact of technological spillovers is sustainability; minimized environmental damages through maximizing the human well-being. The study concluded that foreign R&D spillovers are major channels of transmission through which technology can diffuse across the borders and regions. The empirical results show that the foreign knowledge spillover is essential component for manufacturing growth and it aspires to maximize the technological inflow in Pakistan. Furthermore, the important contribution of technology spillover is dependent on labor force absorptive ability. Results show that labor force has less absorptive ability for efficient use of imported technology while Technology spillover has positive impact on manufacturing growth with less absorptive ability. Therefore, the firm can attain more and efficient production by improving the innovative research, encouragement to innovative thinking and new ideas, and also by improving the labor force skills. Every newly developed technology gets obsolete over the time but innovation makes sense to replace with modern technology.

The estimated result of second model shows that the cointegration relationship and technology spillover can decrease net CO_2 emission in Pakistan's manufacturing sector. The FDI inflow, technology imports and technological transformation expand the manufacturing growth and reduction in Corbin emission. On the basis of this result it is clinched that the technology spillover has direct as well as indirect consequences on manufacturing sector and CO_2 emission. Directly it increases output, reduces energy consumption and CO_2 emission. While indirectly technology spillover enhances internal innovation and accelerates technology transformation, absorptive capacity and efficient utilization of new technology.

It is recommended for manufacturers to voluntarily increase foreign technology and improve the labor force skills through research activities, research workshops, research seminars, and via encouraging the innovative ideas. In addition, government of Pakistan needs to provide incentives to industrialists to upgrade the manufacturing plants, FDI inflow, technology imports and trade openness. Government may use such measures to investigate the magnitude of R&D spillover and firm own efforts of innovation. The study suggests that the manufacturing sector should improve the technology spillover from foreign resources for CO_2 emission reduction. Government and firm policy preferences for sustainable output growth and clean environment are highly dependent on green technology spillover. So, government may opt for demoting the carbon taxes to allow clean technology to overhaul the sordid technology. International knowledge spillover creates both negative as well as positive transboundary pollution, but cross country specific policies targeted to attain efficient technology to reduce negative externality increase the long run social welfare.

References

Alemdar, N. M., & Özyildirim, S. (2002). Knowledge spillovers, transboundary pollution, and growth. *Oxford Economic Papers*, *54*(4), 597-616.

Bank, W. (2018). World development indicators database. *Obtenido de Gross Domestic Product: databank. worldbank. org*.

Bittencourt, P. F., & Giglio, R. (2013). An empirical analysis of technology absorption capacity of the Brazilian industry. *CEPAL review*.

Coe, D. T., & Helpman, E. (1995). International r&d spillovers. *European economic review, 39*(5), 859-887.

Coe, D. T., Helpman, E., & Hoffmaister, A. W. (2009). International R&D spillovers and institutions. *European economic review, 53*(7), 723-741.

Costantini, V., Mazzanti, M., & Montini, A. (2013). Environmental performance, innovation and spillovers. Evidence from a regional NAMEA. *Ecological Economics, 89*, 101-114.

Dalgıç, B., & Mıhç, S. (2013). Technology Spillovers through Imports and Absorptive Capacity in Turkey. *International Journal of Humanitie*, *3*(17), 298-309.

Di Maria, C., & Smulders, S. (2017). A paler shade of green: Environmental policy under induced technical change. *European economic review, 99*, 151-169.

Dupuy, A. (2006). Hicks neutral technical change revisited: CES production function and information of general order. *The BE Journal of Macroeconomics*, *6*(2).

Empora, N. (2017). *Air pollution spillovers and US state productivity growth*. Retrieved from

Fischer, C. (2008). Emissions pricing, spillovers, and public investment in environmentally friendly technologies. *Energy Economics, 30*(2), 487-502.

Galdeano-Gómez, E., Cespedes-Lorente, J., & Martínez-del-Río, J. (2008). Environmental performance and spillover effects on productivity: Evidence from horticultural firms. *Journal of environmental management, 88*, 1552-1561. doi:10.1016/j.jenvman.2007.07.028

Gorkey-Aydinoglu, S. International Diffusion of Technology in the Manufacturing Industry: Emerging Countries within the EU and Turkey.

Gujarati, D. N., & Dawn, C. (2010). Porter.(2009). Basic Econometrics: McGraw-Hill Education.

Hanley, N. (2001). Cost—benefit analysis and environmental policymaking. *Environment and Planning C: Government and Policy, 19*(1), 103-118.

Hanley, N., Shogren, J. F., & White, B. (2016). *Environmental economics: in theory and practice*: Macmillan International Higher Education.

Heal, G., & Tarui, N. (2010). Investment and emission control under technology and pollution externalities. *Resource and Energy Economics, 32*(1), 1-14.

Jebli, M. B., & Youssef, S. B. (2017). The role of renewable energy and agriculture in reducing CO2 emissions: Evidence for North Africa countries. *Ecological indicators, 74*, 295-301.

Jiao, J., Yang, Y., & Bai, Y. (2018). The impact of inter-industry R&D technology spillover on carbon emission in China. *Natural Hazards, 91*(3), 913-929.

Kazmi, S. T. H. (2016). China's Journey in Renewable Energy and Its Potential Spillover Effects through the CPEC in Pakistan. *The Pakistan Development Review*, 619-631.

Kinda, T. (2012). Foreign ownership, sales to multinationals and firm efficiency: the case of Brazil, Morocco, Pakistan, South Africa and Vietnam. *Applied Economics Letters*, *19*(6), 551-555.

Kuo, F. Y., & Young, M. L. (2008). A study of the intention–action gap in knowledge sharing practices. *Journal of the American Society for Information Science and Technology, 59*(8), 1224-1237.

Lee, J. W. (2013). The contribution of foreign direct investment to clean energy use, carbon emissions and economic growth. *Energy Policy, 55*, 483-489.

Lei, D., Shangguan, Z.-P., & Rui, L. (2012). Effects of the grain-for-green program on soil erosion in China. *International Journal of Sediment Research, 27*(1), 120-127.

Liu, W., Xu, X., Yang, Z., Zhao, J., & Xing, J. (2016). Impacts of FDI renewable energy technology spillover on China's energy industry performance. *Sustainability, 8*(9), 846.

Liu, Z., Guan, D., Wei, W., Davis, S. J., Ciais, P., Bai, J., . . . Marland, G. (2015). Reduced carbon emission estimates from fossil fuel combustion and cement production in China. *Nature, 524*(7565), 335-338.

Mayer, J. (2000). Globalization, Technology transfer and skill accumulation in low-income countries. *Globalization, Marginalization and Development*.

Mehmood, T., Chaudhry, M., Tufail, M., & Irfan, N. (2009). Heavy metal pollution from phosphate rock used for the production of fertilizer in Pakistan. *Microchemical Journal, 91*(1), 94-99.

Mingyong, L., Shuijun, P., & Qun, B. (2006). Technology spillovers, absorptive capacity and economic growth. *China Economic Review, 17*(3), 300-320.

Mohammadi, A., Veismoradi, A., Hashemi, H. H., Akbari, P., & Rostami, R. (2015). The Estimation of the Share of Technological Spillover in Sectorial-Regional Growth (Case Study: 29 Production Sectors of 30 Iran Provinces). *Asian Economic and Financial Review, 5*(3), 371.

Mustafa, Z. (2011). *Climate change and its impact with special focus in Pakistan.* Paper presented at the Pakistan Engineering Congress, Symposium.

PWT, (2019) Pann World Table 9.1 *https://www.rug.nl/ggdc/productivity/pwt/?lang=en*

Pavitt, K. (1984). Sectoral patterns of technical change: towards a taxonomy and a theory. *Technology, Management and Systems of Innovation*, 15-45.

Pesaran, M. H., & Pesaran, B. (1997). *Working with Microfit 4.0: interactive econometric analysis;[Windows version]*: Oxford University Press.

Pesaran, M. H., Shin, Y., & Smith, R. J. (1996). *Testing for the'Existence of a Long-run Relationship'*. Retrieved from

Romer, P. M. (1990). Endogenous technological change. *Journal of political Economy, 98*(5, Part 2), S71-S102.

Seck, A. (2012). International technology diffusion and economic growth: Explaining the spillover benefits to developing countries. *Structural Change and Economic Dynamics, 23*(4), 437-451.

Serfraz, A. (2017). *Analyzing short-run and long-run causality between FDI flows, labour productivity and education in Pakistan*. Retrieved from

Shittu, A. I. (2012). Financial intermediation and economic growth in Nigeria. *British Journal of Arts and Social Sciences, 4*(2), 164-179.

Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World development, 32*(8), 1419-1439.

Torras, M., & Boyce, J. K. (1998). Income, inequality, and pollution: a reassessment of the environmental Kuznets curve. *Ecological economics, 25*(2), 147-160.

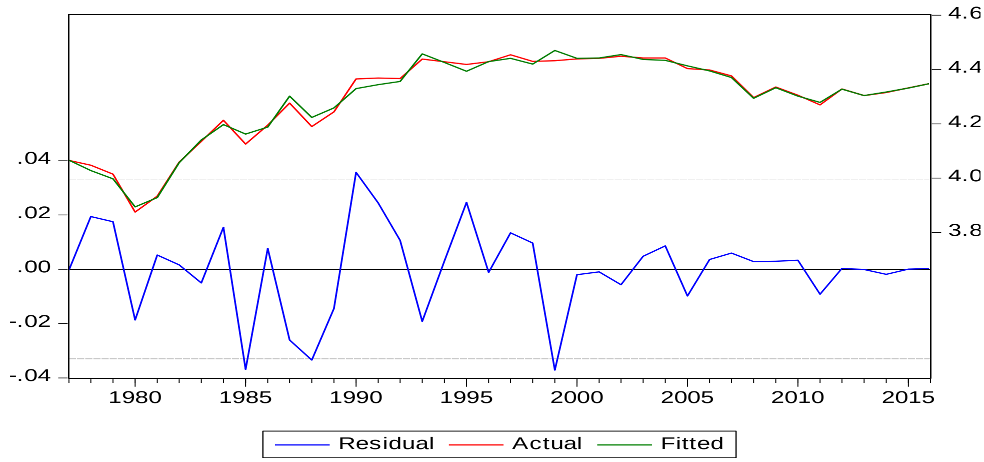
Türker, M. V. (2012). A model proposal oriented to measure technological innovation capabilities of business firms–a research on automotive industry. *Procedia-social and behavioral sciences, 41*, 147-159.

Vayá, E., López-Bazo, E., Moreno, R., & Suriñach, J. (2004). Growth and externalities across economies: an empirical analysis using spatial econometrics *Advances in Spatial Econometrics* (pp. 433-455): Springer.

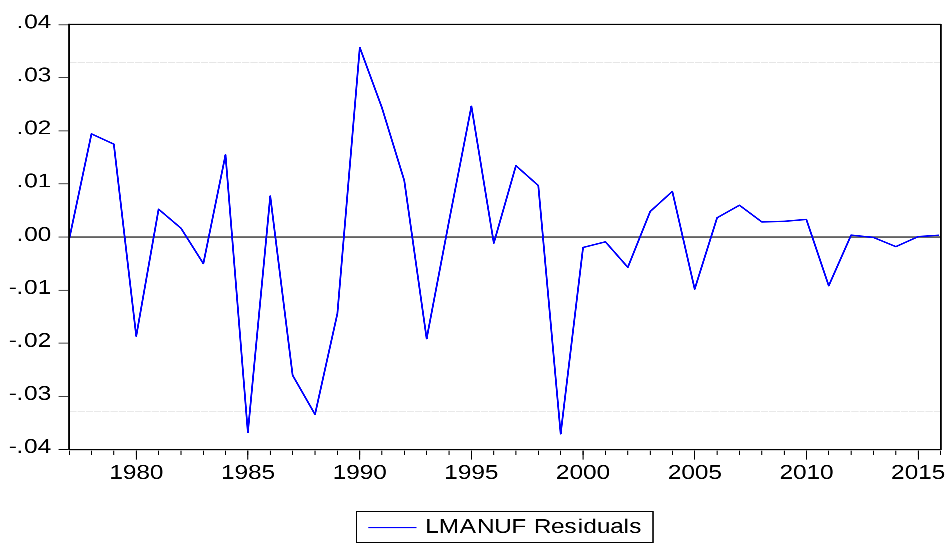
Verma, A. K., Dash, R. R., & Bhunia, P. (2012). A review on chemical coagulation/flocculation technologies for removal of colour from textile wastewaters. *Journal of environmental management, 93*(1), 154-168.

Wang, S. (2015). Research on Technology Spillover Effects on Agricultural Productivity in China.
Wang, X., Fang, H., Zhang, F., & Fang, S. (2018). The spatial analysis of regional innovation performance and industry-university-research institution collaborative innovation—An empirical study of Chinese provincial data. *Sustainability*, *10*(4), 1243.
Youssef, S. B. (2009). Transboundary pollution, R&D spillovers and international trade. *The Annals of Regional Science*, *43*(1), 235-250.
Zarrabi, F., & Vahedi, M. (2012). Alignment between technology strategy and leadership. *Procedia-Social and Behavioral Sciences*, *41*, 23-28.

Appendix



Cumulative Sum (CUSUM)



Cumulative Sum of Square