p-ISSN: 2708-2474
e-ISSN: 2708-2482

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GLOBAL MANAGEMENT SCIENCES REVIEW

HEC-RECOGNIZED CATEGORY- Y

VOL. X, ISSUE I, WINTER (MARCH-2025)

DOI (Journal): 10.31703/gmsr
DOI (Volume): 10.31703/gmsr.2025(X)
DOI (Issue): 10.31703/gmsr.2025(X-I)

Double-blind Peer-review Research Journal
www.gsrjournal.com

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Doi:https://dx.doi.org/10.31703

Article title

Technological Absorption Hypothesis and Productivity Growth in Pakistan Manufacturing Sector

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Keywords: TFP, Solow Residual, Human Capital, Foreign Direct Investment, Transfer of Technology, ARDL Model, Error Correction Model.

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Pages: 27-40
DOI:10.31703/gssr.2025(X-I).03
DOI link: https://dx.doi.org/10.31703/gmsr.2025(X-I).03
Article link: http://www.gmsrjournal.com/article/A-b-c
Full-text Link: https://gmsrjournal.com/fulltext/
Pdf link: https://www.gmsrjournal.com/jadmin/Auther/31rvIolA2.pdf

Global Management Science Review

p-ISSN: 2708-2474 e-ISSN: 2708-2482
DOI(journal): 10.31703/gmsr
Volume: X (2025)
DOI (volume): 10.31703/gmsr.2025(X)
Issue: I (Winter-March 2025)
DOI(Issue): 10.31703/gmsr.2025(X-I)

Home Page
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Volume: X (2025)
https://www.gmsrjournal.com/Current-issues

Issue: I-Winter (March-2025)
https://www.gmsrjournal.com/Current-issues/9/1/2025

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Doi:https://dx.doi.org/10.31703

Citing Article

03	Technological Absorption Hypothesis and Productivity Growth in Pakistan Manufacturing Sector		
Authors	Muhammad Tufail Junaid Ali Hidayat Ullah Khan	DOI	10.31703/gmsr.2025(X-I).03
		Pages	27-40
		Year	2025
		Volume	X
		Issue	I

Referencing & Citing Styles

APA	Tufail, M., Ali, J., & Khan, H. U. (2025). Technological Absorption Hypothesis and Productivity Growth in Pakistan Manufacturing Sector. *Global Management Sciences Review*, *X*(I), 27-40. https://doi.org/10.31703/gmsr.2025(X-I).03
CHICAGO	Tufail, Muhammad, Junaid Ali, and Hidayat Ullah Khan. 2025. "Technological Absorption Hypothesis and Productivity Growth in Pakistan Manufacturing Sector." *Global Management Sciences Review* X (I):27-40. doi: 10.31703/gmsr.2025(X-I).03.
HARVARD	TUFAIL, M., ALI, J. & KHAN, H. U. 2025. Technological Absorption Hypothesis and Productivity Growth in Pakistan Manufacturing Sector. *Global Management Sciences Review,* X, 27-40.
MHRA	Tufail, Muhammad, Junaid Ali, and Hidayat Ullah Khan. 2025. 'Technological Absorption Hypothesis and Productivity Growth in Pakistan Manufacturing Sector', *Global Management Sciences Review*, X: 27-40.
MLA	Tufail, Muhammad, Junaid Ali, and Hidayat Ullah Khan. "Technological Absorption Hypothesis and Productivity Growth in Pakistan Manufacturing Sector." *Global Management Sciences Review* X.I (2025): 27-40. Print.
OXFORD	Tufail, Muhammad, Ali, Junaid, and Khan, Hidayat Ullah (2025), 'Technological Absorption Hypothesis and Productivity Growth in Pakistan Manufacturing Sector', *Global Management Sciences Review,* X (I), 27-40.
TURABIAN	Tufail, Muhammad, Junaid Ali, and Hidayat Ullah Khan. "Technological Absorption Hypothesis and Productivity Growth in Pakistan Manufacturing Sector." *Global Management Sciences Review* X, no. I (2025): 27-40. https://dx.doi.org/10.31703/gmsr.2025(X-I).03.

e-ISSN: 2708-2482 Volume: X (2025) Issue: I-Winter (March-2025) p-ISSN: 2708-2474

Global Management Sciences Review
www.gmsrjournal.com
DOI: http://dx.doi.org/10.31703/gmsr

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Introduction

This study critically examines various growth theories and acknowledges the significant contributions of growth economists such as Adam Smith, David Ricardo, Harrod and Domar, Robert Solow, Paul Romer, J. Benhabib, and M. Spiegel. While the current research heavily draws on both exogenous and endogenous growth theories, it highlights Solow's, 1956 role as the founder of exogenous growth theory, who advanced the earlier Harrod-Domar model by incorporating labor force dynamics. He proposed that the capital-labor ratio is variable and identified saving and population growth rates as key factors influencing steady-state growth. According to Solow, a country's long-term economic growth is determined exogenously. However, the significance of human capital emerged with the development of endogenous growth theory in 1986. Romer (1986) and Lucas (1988) argued that, in contrast to Solow's predictions, long-term economic growth is determined endogenously.

Mankiw et al. (1992) empirically examine the findings of the Solow model and propose an augmented version by incorporating human capital into the production function. They suggest that output is influenced by both physical capital and human capital, with the impact of physical capital being more significant than that of human capital. This enhancement of the Solow model accounts for 80 percent of the variation in income across countries. Additionally, the model supports the Solow convergence hypothesis, which posits that countries tend to achieve different steady-state growth rates based on their saving and population growth rates.

Research indicates that only a small portion of economic growth can be attributed to traditional factors of production, such as the amount of capital and labor hours utilized. The main drivers of economic growth include capital accumulation, improved resource allocation, institutional development, and technological advancements. To eliminate distortions in both the production sector and the input market, it is essential to focus not only on technical efficiency but also on allocative efficiency. The removal of these distortions significantly boosts output, as predicted by Kemal and Naqvi (1992). However, protectionist policies have distorted the product market, leading to efficiency losses that account for six percent of the gross national product.

Key factors that collectively drive the growth of a nation's economy include resource availability and technological advancement. Technological progress has an important role in enhancing the productivity of inputs into production and can be divided into two categories: human-centered and non-human or disembodied technological changes. Embodied technological change involves the application of advanced technologies and the integration of modern production techniques into capital goods, as evidenced by gross investment ratios. Consequently, a slowdown in investment in such technologies may hinder sustained economic growth. On the other hand, disembodied technological change emerges from improvements in managerial skills, information quality, human resource capabilities, and learning processes. For a developing country to reap the benefits of both general and specific technological changes, it must possess a robust capital goods industry or actively engage in research and development programs.

Thus, an increase in productivity not only enhances output but also boosts the competitiveness of the industrial sector at both national and international levels. In recent years, amid globalization and liberalization, where governments have reduced their intervention in the economy, analyzing the productivity index of the industrial sector operating in a competitive international environment has become essential. Total Factor Productivity (TFP) serves as the most comprehensive indicator of both overall and sector-specific productivity rates. Unfortunately, research in this area has been limited in Pakistan due to restricted access to data sources. Early efforts to estimate TFP include studies of Kemal and Islam (1992), and Wizarat (1981); however, they face challenges stemming from outdated and inadequate data sets, which hinder the generalizability of their findings. Additionally, attempts to identify the macroeconomic sources of TFP, such as the work by Pasha et al. (2002), Khan (2006), Mahmood et al. (2023), Rehman et al. (2023), Ali and Akher (2024) and Awan and Yaqoob (2023) are similarly limited as they primarily focus on aggregate data and emphasize input factors as the main source of long-term growth.

This study aims to re-examine productivity growth in Pakistan's manufacturing sector using a new dataset on capital stock along with other macroeconomic factors for a more recent period compared to existing literature. By doing so, this research intends to address gaps in the current literature and contribute new insights into the factors that influence productivity growth.

Literature Review

The relationship between technological absorption and the national growth rate has been the focus of economists through many years of research. Benhabib and Spiegel (1994) employed cross-country data from 1965 to 1985 to prove human capital serves as the main determinant for economic growth through total factor productivity. The model contains essential elements that form its core components. Romer (1990a) verifies that human capital stands as the key determinant that influences domestic technological advancements in their speed of development. The stock of knowledgeable workers supports better utilization and acquisition of international technology based on research from Nelson and Phelps (1966).

The study delivers two fundamental discoveries which are essential to the research. According to research human capital stock discrepancies between nations explain most of the changes observed in their growth rates during different time periods. A solid human capital stock in countries starting behind will enable them to surpass leading nations in technology adoption during a defined timeframe. The continuous expansion of human capital stock allows countries to become technological leaders provided their human capital endowment remains balanced.

The research on human capital investment and productivity in the United States was done by Black and Lynch in 1996. The researchers tested Cobb-Douglas production functions with and without restrictions and established that human capital and particular forms of employer training specifically education play essential roles in productivity across the manufacturing and non-manufacturing sectors. Their study had to overcome problems with both endogeneity issues and measurement errors. They employed the Generalized Method of Moments (GMM) because it solved the observed problems. A rise in employee education level by ten percentage points resulted in a manufacturing sector productivity growth of 8.5% while the non-manufacturing sector experienced growth of 12.7% according to the unrestricted Cobb-Douglas model. Under the restricted Cobb-Douglas framework both manufacturing productivity grew by 4.9% and non-manufacturing productivity rose by 5.9%. Researchers at Maudas et al. (1999) evaluated data from OECD countries between 1975 to 1990. The study adopted the Barro and Lee (1993) model specification with its main analysis dedicated to Japan and USA. The research demonstrates that human capital quality acts as a main factor that influences total factor productivity (TFP). When human capital factors are omitted from the regression model both the USA and Japan would undergo significant positional changes in their productivity rankings. Prescribing human capital as an input element makes Japan more efficient and productive according to productivity assessments. The researchers split TFP into technical alterations and efficiency variations since these factors cause measurement biases. The research showed Japan achieved higher efficiency gains compared to other countries which accounted for its different relative position. Meanwhile, all OECD countries exhibited similar technological changes.

Chand and Sen (2002) applied the neoclassical growth model to understand how the manufacturing sector's total factor productivity growth responded to trade liberalization in India. The researchers establish through their hypothesis evaluation that India's trade liberalization program develops slowly which justifies why pre- and post-analysis becomes invalid. The researchers discovered that the trade liberalization impacts affect intermediate and final goods industries differently. TFP gains from trade liberalization in intermediate goods sectors surpass those of final goods sectors since the latter shows negative effects. From 1992 to 1996 Djankov and Hockman (2002) used Czech Republic firm data to study how foreign investment affects total factor productivity growth. The explanatory variables in this analysis share a connection with productivity which causes bias and inconsistency in the Ordinary Least Squares (OLS) results. The research used a Hausman specification test to determine between implementing the random effects and fixed effects models. FDI contributes positively to domestic firms by driving their total productivity growth according to the authors. The host country received both machinery and blueprints classified as hard technology from foreign investors while acquiring managerial skills and information which fell in the category of soft technology. FDI led to worse outcomes for domestic firms who joined ventures with foreign investors than domestic firms who received no foreign direct investment whatsoever. Shenggen Fan et al. (2002) conducted research that evaluated both primary and secondary government expenditures toward rural poverty eradication as well as agricultural productivity growth. Government investments that enhanced agricultural productivity resulted in higher wages as well as more investment and non-agricultural job opportunities which substantially decreased poverty levels. Calderón and Lin (2002) examined the direction of causality between financial development and economic growth. Their study found bidirectional causality between the two, indicating that financial development fosters growth through the rapid accumulation of capital and technological advancements. The impact of financial development is more pronounced in less developed countries compared to developed nations.

Abdul Jalil and Ying Ma (2008) conducted research on the same relationship between variables in Pakistan and China. China experienced positive economic growth because its deposit liability ratio remained significant. China demonstrated an insignificant relationship between economic growth and credit provided to the private sector. Kasahara and Rodrigue (2008) studied a Chilean manufacturing plant panel from 1979 to 1986 to verify if intermediate goods importation improved manufacturing site performance. Plants experience a productivity increase of 3.4% to 22.5% when they start importing intermediate goods compared to remaining non-importers. Foreign technology diffusion along with domestic technology advancement occurs when firms import intermediate products. Labor and capital persist as the major forces behind manufacturing growth yet human capital and TFP make up around one-third of total manufacturing additions that remain lower than what some developing societies achieve. The research conducted by Hamid and Pichler (2018) investigated value added alongside productivity growth patterns in Pakistan's manufacturing industry. A translog specification system of the production function was used to analyze data from 1971-72 to 2004-05. Spanish firms experienced an impact on their Total Factor Productivity between 1991 and 2002 because Augier et al. (2013) studied how the input of intermediate goods and capital equipment affected their TFP. The research findings demonstrated that importing intermediate goods alongside capital equipment yields increases in TFP. Firms that focus on skilled labor receive superior improvement in TFP than other types of businesses. Firms that maintain 75% or more skilled workers gain two times more productivity enhancement compared to organizations with fewer skilled employees. Based on the literature review, the following hypothesis has been developed for the current study:

Hypothesis-1: Investing in human capital directly influences productivity growth in the manufacturing sector

Hypothesis 2: The opening of the economy to international markets consistently promotes productivity growth in the manufacturing sector.

Hypothesis-3: The transfer of technology from developed to developing countries enhances productivity in the manufacturing sector.

Hypothesis-4: Financial development in a country is one of the key factors for increasing productivity in the manufacturing sector.

Hypothesis-5: Government expenditure on development projects is also a key factor in promoting productivity growth.

Data and Research Methodology

Data on the variables included in the model has been collected from archival records for the period from 1973 to 2018. It was obtained from the Pakistan Bureau of Statistics, the Pakistan Economic Survey, and the Census of Manufacturing Industries. The variables used for total factor productivity (TFP) include GDP, employment levels, GFCF, Interest rate, and nominal wages. Additionally, human capital, export diversification, FDI, machinery and intermediate goods imports, and government development spending data were obtained from the "50 Years of Pakistan Statistics book."

The analysis is conducted in two steps. First, growth accounting is employed to calculate TFP. In the second step, the study examines the impact of macroeconomic factors on TFP, providing a comprehensive evaluation of how these factors influence productivity trends.

Variables Construction

The growth accounting framework utilized in this study was initially developed by Stigler (1947) in a conceptual context and later refined by Kendrick (1961) through specific measurements. This methodology provides a comprehensive approach for distinguishing between input factors and technological elements that contribute to economic growth. It allows for a thorough analysis of various inputs, such as labor and capital, and their interactions with technology to enhance productivity. To delineate the contributions of input factors and technological changes to manufacturing growth, the standard neoclassical production function is employed.

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

For calculating the TFP the following equation has been derived from equation 1.

$$\frac{\mathring{A}(t)}{A(t)} = \frac{\dot{Y}(t)}{Y(t)} - r.\frac{K(t)}{Y(t)}\frac{\acute{K}(t)}{K(t)} - w.\frac{L(t)}{Y(t)}\frac{\dot{L}t)}{L(t)} \quad (2)$$

The series of capital stock was obtained by using the following method.

$$K_t = I_t + (1 - \delta)K_{t-1} \quad (3)$$

K_t and I_t represent the stock of capital and gross investment for the base period, respectively. Sigma (δ) denotes capital depreciation.

Empirical Methodology

Total Factor Productivity (TFP), as estimated through the growth accounting framework outlined in the preceding section, is analyzed in relation to key macroeconomic variables. To test the hypothesis regarding the manufacturing sector's capacity to absorb technological advancements—an ability shaped by factors such as human capital, trade openness, technology transfer, and public development spending—this study adopts the modeling approaches developed by Savvides and

Zachariadis (2004) and Anders (2007). The model is generally specified as follows:

TFP = f (human capital, economic openness, technology transfer, government development expenditure, financial development)

$$TFP = f\,(HC\,, OP\,, TT, DE,\ FD) \tag{4}$$

In this study, Total Factor Productivity (TFP) is employed as a proxy for technological progress to measure productivity growth. Human capital (HC) plays a pivotal role in the model, and the literature presents a variety of approaches to its measurement. For example, Hall and Jones (1999) and Maudos et al. (1999) assessed human capital based on workers' educational attainment, while the mean years of schooling of the worker were used by Benhabib and Spiegel (1994). Hamid and Picher (2018) evaluated human capital by considering enrollment ratios in secondary, tertiary, and vocational education relative to the labor force. This research defines the use of government expenditure in education and vocational training as a proxy for human capital, following the approach adopted by Baldwin, Diverty, and Sabourin (1995).

The variable 'OP' refers to the economy's degree of openness, a concept interpreted differently across theoretical and empirical literature. The effective rate of protection was used by Ferreira and Rossi (2003), whereas Jajri (2007) and Malik et al. (2010) measured openness through the trade to GDP ratio. In this study, due to data limitations, the trade to GDP ratio is adopted, calculated using available data on exports, imports, and GDP.

The variable 'TT' represents technology transfer, which commonly occurs through channels such as FDI, and IM. In this context, technology transfer is measured using FDI inflows and IMg. DE signifies government development expenditure, which has been widely recognized for its role in enhancing TFP and mitigating rural poverty. Studies such as those by Aschauer (1988) and Shenggen et al. (2002) emphasize that public investment—particularly in research and development—stimulates productivity growth, resulting in higher wages, increased investment, and expanded employment opportunities across both agricultural and non-agricultural sectors.

$$TFP = f\,(HC\,, OP\,, TT, DE,\ FD) \tag{5}$$

To account for technology transfer, the above equation will be adjusted to include its key determinants:

$$TT = f\,(FDI\,,\ IM_g) \tag{6}$$

$$TFP = f\left(HC\,, OP\,, FDI\,,\ IM_g\,, DE,\ FD\right) \tag{7}$$

Empirical specification of the above model,

$$TFP_t = a_0 + a_1 HC_t + a_2 OP_t + a_3 FDI_t + a_4 IMg_t + a_5 DE_t + a_6\, FD + u_t \tag{8}$$

Hence, once the equation is obtained, the next step is to identify the main factor affecting total factor productivity. This will also give us insight into facts about the manufacturing sector.

Econometric Model

According to time series literature, variables specified at level or non-stationary are likely to give spurious estimates through OLS estimation. To get rid of this issue the method of taking difference can be applied but this also has a problem. Taking differences will lead to the loss of long-run relations from the series. To overcome these challenges, economists have developed various techniques to identify long-term relationships between variables. The most proponents of them are the Engle-Granger (1987) test, the Johansen cointegration test (1988, 1991), and the Johansen and Juselius (1996) test. Almost all of them have some limitations; Engle-Granger will not work if variables are integrated in a different order. Likewise, for a small sample size, the aforementioned techniques can't be applied.

To address these limitations, this study utilizes the technique introduced by Pesaran (2012), widely known as the ARDL model. This approach effectively overcomes the shortcomings of other cointegration methods. Additionally, the ARDL model is suitable for small sample sizes. Before applying any of the mentioned techniques, it is crucial to test the stationarity of the time series. If the data is stationary and the series has the same order of integration, methods like the Engle-Granger or OLS techniques can be used. Otherwise, the ARDL model becomes the preferred choice.

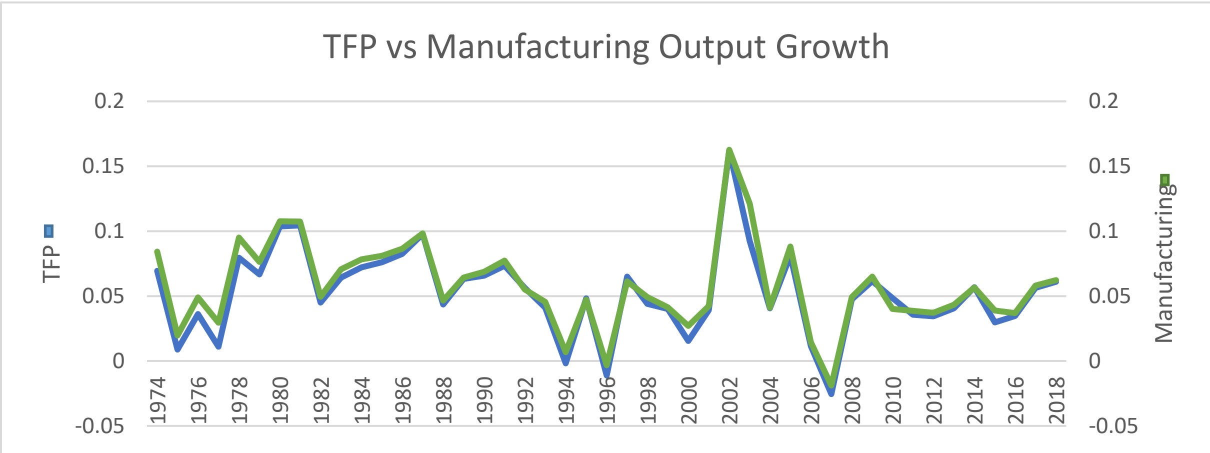
Result and Discussion

When Pakistan achieved independence, its economy relied heavily on agriculture while its industrial capacity remained substantially restricted. The newly formed Pakistan obtained just 34 out of the 955 industrial units in the region. Large-scale and small-scale industrial units combined for less than 6.4% of GDP growth during this time. The government established the Pakistan Industrial Development Corporation (PIDC) in 1952 to invest in industrial projects which needed substantial initial capital. PIDC started essaying new measures in 1958 to boost manufactured goods exports through both an export duty cut and an export bonus system. The industrial sector maintained a growth trajectory in GDP contributions which led to its share rising from 9.7% during 1954-55 to 11.9% during 1959-60.

The transformation from consumer goods toward heavy industries during the 1960s sparked remarkable industrial sector growth within the second five-year plan. The manufacturing sector experienced growth at 7.8% while showing progress when compared to 4.6% in 1955. However, between 1971 and 1977, industrial growth experienced a significant decline in terms of exports and productivity. This downturn was primarily attributed to nationalization, the separation of East Pakistan, and the loss of the domestic market. During this period, the annual growth rate of the manufacturing sector dropped to 2.8%.

In the 1990s, the manufacturing sector recorded negative growth (-1.9%), a stark contrast to the positive growth observed in the 1980s. At the start of the 21st century, the manufacturing sector showed impressive growth, reaching over 14% in 2004-05. However, in subsequent years, the sector's growth rate fluctuated between -2% and 8.8%. The graph below illustrates the relationship between TFP and manufacturing sector output growth.

Figure 1



Similarly, the graphical relationship between the TFP and its determinant is given in Appendix B.

Unit Roots Test

The results from the ADF test show whether the variables in your dataset exhibit stationary behavior. Stationarity functions as an essential property for time series analysis because statistical variables keep the same properties of mean and variance throughout time.

Table 1

	ADF Unit Root Test			
Variable	At	T-Statistics	Prob	Integration
FDI	Level 1st Difference	-1.41 -5.17	0.84 0.00	I(1)
Development Expenditure	Level 1st Difference	-0.39 -4.41	0.98 0.00	I(1)
Human Capital	Level 1st Difference	0.09 -7.45	0.96 0.00	I(1)
Trade Openness	Level 1st Difference	-3.71 -	0.00 -	I(0)
IM (machine& goods)	Level 1st Difference	-2.37 -	0.02 -	I(0)
FD	Level 1st Difference	0.56 -5.30	0.83 0.00	I(1)
Manufacturing TFP	Level 1st Difference	-0.48 -4.89	0.99 0.00	I(1)

The results show TO and IM to be stable at their observed levels because HC, FDI, DE, FD, and TFP reach stationarity only through first-differencing. The ADF test demonstrates that different integration orders exist for the analyzed variables. An ARDL model stands as the appropriate tool for identifying lasting variable relationships between the variables in these pairs.

Autoregressive Distributive Lag Model

The estimated coefficients from the ARDL model are presented in Table 2, with each coefficient accompanied by its standard error and t-statistic. The cointegration results were assessed using the Wald restriction test. Additionally, the model's goodness of fit was evaluated through several diagnostic tests, including the Breusch-Godfrey Serial Correlation LM Test, the ARCH Test for heteroscedasticity, the Jarque-Bera Normality Test, and the Ramsey RESET Test for model specification. The outcomes of these diagnostic tests are detailed in Appendix Tables 2 and 3.

The diagnostic results confirm that the model meets the necessary econometric criteria. Specifically, there are no signs of model misspecification, and the residuals are free from serial correlation, normally distributed, and homoscedastic. These properties support the validity and reliability of the estimated results.

Analysis using the Wald test for cointegration resulted in an F-statistic value of 6.69 that surpasses the upper bound critical value of 4.43 Pesaran et al. (2000) critical value bounds table (Appendix, Tables 1–2). The results support cointegration between the variables because the null hypothesis of no equilibrium relationship is efficiently rejected.

Table 2

Dependent: Manufacturing TFP	ARDL Long-run Result		
Variable	Coefficients	T-Statistics	Prob
FDI	0.211	1.97	0.062
Development expenditure	0.527	4.17	0.001
Human Capital	0.547	2.46	0.007
Trade Openness	0.452	1.78	0.068
IM(machine& goods)	0.310	2.99	0.004
FD	0.909	2.04	0.03

The results from the long-run ARDL model, as summarized in the corresponding table, confirm that all estimated coefficients align with theoretical expectations. The coefficient for Foreign Direct Investment (FDI) is 0.211 and statistically significant at the 5% level, indicating that a 1% increase in FDI contributes to a 0.211% rise in total factor productivity (TFP) within the manufacturing sector. FDI serves as a vital channel for the diffusion of advanced technologies from developed to developing economies. It supports the stabilization of demand for domestic inputs, facilitates the utilization of local raw materials, and introduces improved managerial strategies, marketing techniques, and innovative technologies. While existing literature does acknowledge potential adverse effects—such as the displacement of domestic investment or the economic burden from profit repatriation—the broader consensus suggests that the socio-economic benefits of FDI outweigh its drawbacks. This study confirms the positive and significant relationship between FDI and productivity in Pakistan's manufacturing sector.

The level of human capital directly affects productivity rates within a country or region. The output of total factor productivity (TFP) increases by 0.547% when government education and vocational training funding rises by 1 percentage point of GDP. These findings echo the conclusions of Black and Lynch (1996), who emphasized the productivity-enhancing effects of training investments, particularly in manufacturing environments.

The theoretical and empirical analysis also supports the view that transitioning from protectionist trade policies to more liberal and open trade regimes is advantageous for domestic development. For example, Kemal & Naqvi (1992) calculated that protectionist measures caused Pakistan to lose resources equivalent to 6% of its national Gross National Product. The removal of trade barriers through international trade creates two benefits: elimination of economic distortions and access to modern intermediate materials and advanced technological expertise. The findings of this study align with the trade openness hypothesis, showing that a 1% increase in trade openness results in a 0.452% increase in TFP in the manufacturing sector.

National bulk purchases and imported machinery and intermediate goods function as vital strategies to transfer technology from countries border to border. Countries achieve technological development and stimulate economic growth through the strategic use of these channels. Research has demonstrated that imports from technologically advanced countries positively influence productivity, particularly in industries that are more skill-intensive. Firms in these sectors experience greater learning effects and technology externalities in their operations compared to low-skill-intensity firms. These findings support the hypothesis that manufacturing productivity is boosted by imports of intermediate goods and machinery, with a 1% increase in imports leading to a 0.310% increase in manufacturing productivity.

Government development expenditure aligns with previous expectations, as public investment in infrastructure and services such as roads, highways, and railways positively affects economic growth. The results also indicate that government development expenditure leads to a 0.527% improvement in TFP in the manufacturing sector. Additionally, a 1% rise in domestic grants contributes to a 0.366% increase in TFP.

Finally, the most influential argument is that financial development and trade openness positively impact market reforms and drive TFP growth. In fact, financially developed countries with open financial and trade systems demonstrate higher economic growth compared to those with limited financial and trade opportunities. Consequently, the hypothesis that the growth of the financial sector boosts productivity is supported by the findings of this study, which indicate that a 1% increase in financial development results in a 0.909% rise in manufacturing productivity.

Table 3

The Result of the Error Correction Model

Variable	Coefficient	Std.Error	t-Statistic
C	-2.639	1.007	-2.621
DLDE	0.049	0.013	3.804
DLDE_1	-0.066	0.024	-2.717
DFD_1	-0.018	0.020	-0.898
DLHC	-0.049	0.083	-0.583
DLFD/GDP	-0.395	0.160	-2.467
DLOP	-0.102	0.093	-1.090
DLIM	0.085	0.041	2.044
DTFP_1	0.390	0.234	1.663
ECM 1	-0.557	0.320	-1.743

Error Correction Model

The error correction term maintained a negative value with a statistical significance of 10% when used in the error correction model. The estimated error correction term demonstrates both effective short-run dynamic capture and successful long-run equilibrium guidance of the model. The ECT coefficient value of -0.557 demonstrates that about 56% of the previous period equilibrium deviation gets corrected within the current period. The data implies quick adjustments occur because of this system's design. This finding confirms the stability and responsiveness of the manufacturing sector in the presence of short-term shocks (Appendix: Tables 4–6).

A closer examination of the short-run dynamics reveals that human capital exhibits a negative and statistically insignificant coefficient, aligning with the economic argument that investments in education and vocational training are inherently capital-intensive, and their productivity-enhancing effects become apparent only in the long term. In the short term, such investments may raise fiscal burdens or divert resources, thus explaining the negative coefficient.

Similarly, the results show that FDI, financial development, and trade openness have negative coefficients in the short-run model. This suggests that, in the short term, FDI and trade liberalization may negatively affect productivity. However, these variables are expected to have a positive impact on productivity over time, as their effects foster the diffusion of technology, knowledge spillovers, and the reduction of distortions in both product and factor markets.

However, the short-run coefficients for imports of machinery and intermediate goods, as well as government development expenditure, align with expectations, indicating a positive impact on manufacturing productivity. Based on the results, it can be inferred that expenditure on capital goods and infrastructure has a direct positive effect on productivity in the short run.

Conclusion and Policy Recommendation

This paper explores the factors influencing TFP in Pakistan's manufacturing sector, utilizing the growth accounting framework, the ARDL model, and the ECM Model. This research investigated the impact of human capital alongside trade openness and foreign direct investment (FDI) and imports of machinery and intermediates alongside financial sector development and government development expenditure throughout the years 1973 to 2018. The findings contribute to a deeper understanding of the determinants of productivity growth in the manufacturing sector and offer valuable insights for formulating policies aimed at achieving sustainable economic growth.

Integration among the variables highlights that FDI, human capital, imports of machinery and intermediate goods, financial development, and government development expenditure all have a positive effect on manufacturing productivity in the long term. FDI plays a key role in facilitating technology transfer and improving management and market conditions, while trade openness fosters a more competitive environment and provides access to advanced technologies and intermediate inputs. Likewise, government spending on infrastructure and education enhances TFP by addressing market failures in the provision of public goods. While the long-term analysis reveals the positive contributions of human capital, FDI, and trade openness to the economy, the short-term analysis suggests that these factors initially impose costs on the economy, reflecting the high upfront investments required.

The research results from the ECM above confirm the model's capability, indicating that 56% of any disequilibrium is self-corrected in the subsequent period. This reflects an inherent strength of Pakistan's manufacturing sector, provided that careful macroeconomic engineering is applied.

Policy Recommendations

Empirical research findings allow policymakers to develop recommendations that will boost manufacturing sector productivity in Pakistan:

Building Human Capital as an Investment

Education and vocational training deserve the focus of government leadership initiatives as the primary sources of sustainable productivity. This level of expenditure on education should also be spent on technical and vocational courses so that the manpower that is being produced suits the needs of a modern industrial society.

Promoting Trade Openness

Trade liberalization policies can only be sustained and deepened to enhance the manufacturing sectors linkage into the global value chain. The removal of high tariffs inhibiting machinery and intermediate goods will enhance technological transfer thereby increasing efficiency through access to better technology.

Promoting Foreign Direct Investment

Governments need to construct policies that would encourage FDI worldwide in sectors likely to positively impact technology transfer and dissemination. The availability of the proper macroeconomic fundamentals and doing away with the existing institutional impediments will make Pakistan an ideal investment hub.

Development Expenditure

An increase in public capital expenditure on areas such as transportation, power, utilities, and communication is essential for reducing production constraints and enhancing the competitiveness of the manufacturing industry.

Upgrading of Financial Development.

Relative to manufacturing, the financial sector needs to be enlarged and reformed. They should therefore focus on enhancing the SMEs' access to credit, which is the drive of the industrial segment.

Supporting Research and Development.

There is a needed connection between the science, academic, and commercial worlds as a result of the innovation's promotion. The type of government help that can complement the domestic firms' capability to use foreign technologies vis-à-vis fund R&D work is important.

Reducing Disruptions on the Short-Term

The negative impacts of short-term oriented measures, including trade liberalization and education investments, should be offset by the implementation of other structural reforms, such as safety nets or targeted subsidies to address the social or industrial costs of change.

Adopting these suggestions will help Pakistan develop its manufacturing industry as a key catalyst for economic growth. The results emphasize the importance of systemic policies, along with human resources, technology, and macroeconomic strategies, in supporting sustained long-term productivity growth and enhancing global competitiveness.

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Appendix A

Table 2

Test Summary

Wald Restriction Test	6.6948 (p = 0.0006)	R^2	0.773597
Durbin-Watson Statistic	2.030597	Adjusted R^2	0.555955
F-statistics of ARDL	4.0883 (p = 0.001459)		

Table 3

Robustness of the Model and Diagnostic Checking

Breusch-Godfrey Serial Correlation LM test	0.11910	p = 0.9086
Jarque-Bera Normality test	0.758489	p = 0.6843
Heteroskedasticity: Breusch-Pagan-Godfrey test	7.40405	p = 0.4955
Heteroskedasticity: ARCH test	0.060997	p = 0.8049
Ramsey RESET / Specification test	1.648672	p = 0.2131

Table 4

Test Summary

F-statistics	4.265424 (0.001400)	R^2	0.773363
Durbin-Watson stat	1.995872	Adjusted R^2	0.592053

Table 5

Robustness of the Model and Diagnostic Checking

Breusch-Godfrey Serial Correlation LM test	0.964826	Prob. [0.6173]
Jarque-Bera Normality test	1.274899	Prob. [0.5286]
Heteroskedasticity: Breusch-Pagan-Godfrey test	5.40405	Prob. [0.3705]
Heteroskedasticity: ARCH test	0.020483	Prob. [0.8870]
Ramsey RESET test / specification test	0.250964	Prob. [0.6222]

Figure 1

CUSUMS

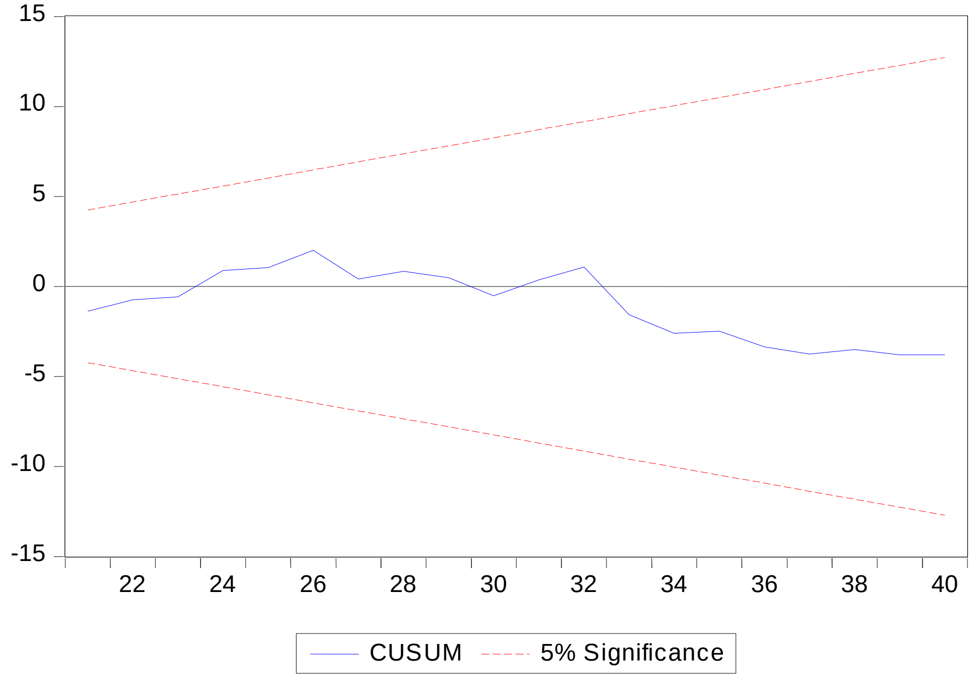

Figure 2

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