Article

Econometric Analysis of Total Factor Productivity in India

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Abstract

This article attempts to investigate the potential relationship and significance of various determinants of Total Factor Productivity (TFP) in India for the 1980–2016 time period. Specifically, this is achieved in two stages. In the first, the standard growth accounting approach is used to measure the changes in TFP. Then, the main model for establishing the determinants of TFP growth is estimated using the autoregressive distributed lag (ARDL) model. Our results suggest that inflation and financial development have a statistically positive impact on TFP. Foreign direct investment, imports, and capital formation are found to have a positive but insignificant impact on the TFP. On the other hand, exports, government size, and natural calamities have a statistically negative impact on TFP. Therefore, in order to accelerate the TFP, governments and policymakers need to design and implement policies to increase financial access to the private sector, while maintaining price stability; exports of high-value products; and increased economic integration in the global economy to benefit from foreign investment flows, which brings in new technology.

JEL Classification: O4, O40, O47

Keywords

Economic growth, total factor productivity, determinants, ARDL model, India

1. Introduction

Over the past few decades, the Indian economy is growing with dramatic pace. Gross domestic product (GDP) per capita has accelerated from moderate 3.5% in the 1980s to over 7% during the first decade of the twenty-first century (Das et al., 2010). The adoption of economic reforms in the early 1990s has paved the way for India to achieve a higher growth path (Ahluwalia, 1994). Despite the accelerated growth, the economic gap between India and other developed countries has not narrowed much. The

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differences in the living standard both within the country and relative to other developed countries remain profound. Reducing income disparities has remained the central focus of Indian policymaking. This stands for evidence of why economic growth and productivity is still at the central stage of empirical research. The theory of economic growth presents a number of alternative models to establish the source of economic growth. The neoclassical theories, along with Marxian view, attach greater significance to technology-driven productivity growth, while new/endogenous growth theory assigns greater weight to factor accumulations. The past studies, including that of Klenow and Rodriquez-Clare (2005), Easterly and Levine (2002) and Wong (2007), highlighted the important role of productivity in improving output growth rates. However, the studies of Young (1995) and Krugman (1994) on East Asian experience of dramatic growth have cast doubt on the role of productivity or efficiency-driven growth. Both of these studies opined that East Asian growth is more a result of *scale effect* than that of technical innovations or factor productivity.

TFP or multi-factor productivity defines the extent to which the existing capacity of a country can produce higher output without raising the inputs over time. Putting it simply, TFP is a difference between measured output and measured inputs. Primarily, two underlying factors may be responsible for such a difference. These include efficient utilisation of available resources (technical efficiency) and the adoption of sophisticated technology. Technological advances enable a country to shift its production frontier outwards, while the former allows it to produce near or on the production frontier. Overall, TFP is a measurement of improvements in the efficiency of resource consumption in production processes.

At the cross-country level, the underlying factors that result in growth and productivity differentials have received considerable attention. Howitt (2000) and Klenow and Rodriquez-Clare (2005) argued that slow technological diffusion from industrialised countries to less developed ones resulted in such growth and productivity differentials. While Restuccia and Rogerson (2008) suggested that misallocation of resources among firms has an important bearing on growth and factor productivity differentials. Though the factor productivity differentials have received much attention, its determinants have remained empirically under-tested.

Theory of economic growth has propounded numerous determinants of growth, ranging from pure economic, social to cultural and institutional factors. In this context, the literature flourished to establish the proximate determinants of growth and TFP. Through a study to establish determinants of growth, Kim and Loayza (2017) identified five main determinants. These include innovation, education, physical infrastructure, institutional infrastructure and market efficiency. Using data from over 65 countries for the 1985 to 2011 sample period, Kim and Loayza (2017) concluded that the variability in TFP across the countries is highly sensitive to physical infrastructure and least sensitive to institutional infrastructure. Whereas, education, market efficiency and innovation are found to have moderate effects. In a similar cross-country study, Miller and Upadhyay (2000) investigated the impact of trade policy, outward orientation and human capital on TFP across 83 countries (both developed and developing). The authors computed TFP through aggregate production function with and without human capital as an input in the production function. The results suggest that trade policy, trade orientation and human capital are positively associated with TFP. However, in the case of least developed countries, human capital affects TFP only after interacting with trade openness. The role of human capital in productivity was further studied by De La Fuente (2011). The study used a Cobb–Douglas production function with constant returns to scale for different specifications of human capital. Using a quinquennial data for the Organisation for Economic Co-operation and Development (OECD) countries over the period from 1960 to 1990, the study found that human capital is a significant determinant of TFP. The significance improves further by using more reliable series of education and adjustment for country-specific fixed effects.

Many studies examined the determinants of TFP at a country level in both the panel and time series setting. Using panel data of different regions of Italy over the period from 1980 to 2001, Bronzini and Piselli (2009) examined the relationship between TFP, research and development (R&D), human capital and public infrastructure. The study concluded that TFP is predominantly impacted by human capital. The second factor affecting TFP is R&D and public infrastructure. Maiti (2013) investigated the implications of trade reforms of the Indian economy on productivity. The study argues that the effect of trade reforms on productivity is biased unless controlled for market distortions. The study estimated modified factor productivity adjusted for market imperfections, using disaggregated industry-level data at the three-digit level for 15 states from 1998 to 2005. The study found that trade reforms have increased (decreased) wage rents in export-competing (import-competing) sectors. In spite of this, trade reforms still have a significant impact on productivity growth. Hsieh and Klenow (2009) raised a question regarding the basis of differences in TFP among countries and argued that differences exist, not because of the technology but because of the misallocation of resources across firms. Comparing India and China to the USA, the study found that on the hypothetical reallocation of labour and capital on the same lines as in the USA, productivity is raised from a range of 30% to 60% in both the countries. However, all of the above-cited studies have employed the ordinary least squares regression. Given the various shortcomings of the ordinary least squares method, the present study is articulated to establish the proximate determinants of TFP in India, using the robust technique of autoregressive distributed lag (ARDL) model. The twin objective of this study is to (a) identify the main determinants and (b) to assess their relative significance in enhancing TFP at the aggregate level. Most of the earlier studies have assessed this relationship in growth rate form. However, one important caveat raised by Hall and Jones (1999) is the information loss in growth rate regressions. Taking note of this, our estimation approach is based on levels rather than growth rates of underlying variables.

The results of the present study are suggestive of the long-run equilibrium or cointegration between TFP and its determinants. Precisely, inflation and financial development have a statistically positive impact on TFP. Foreign direct investment (FDI), imports and capital formation are found to have a positive but insignificant impact on TFP. On the other hand, exports, government size and natural calamities have a statistically negative impact on TFP.

The remainder of the article is organised as follows: Section 2 presents model specification and ARDL approach of cointegration. Section 3 presents the empirical results and their discussion. Section 4 discusses the conclusion and policy recommendations.

II. Data, Modelling Framework and Methodology

This section presents model specification and ARDL approach of cointegration. Various variables employed in the present study and data sources are listed in Appendix 1.

Model Specification

Specification of Aggregate Production Function

We start with two-factor linearly homogenous Cobb–Douglas production function along the lines of Solow (1957) model, as follows:

$$Y_t = A_t K_t^{\alpha} \left(\mathrm{HL}\right)_t^{1-\alpha} e^{u_t} \tag{1}$$

where Y_t is aggregate output (real GDP), K is the aggregate stock of capital, HL is human capital–augmented labour force. The expression A_t is an index of TFP and is often considered as a measure of the *efficiency* with which inputs are used in the production process. The growth rate of technological progress is assumed to be constant. α is a positive exponent, representing the share of capital in output. The complement of the capital share gives the share of labour in output. The exponents of factor inputs are assumed to sum unity. The regression error (u_t) captures all other variables omitted from Equation (1), which may be difficult to measure. The process of estimating Equation (1) is described as follows:

Dividing Equation (1) both sides by L and taking natural logarithms, we get

$$\log\left(\frac{Y_t}{L_t}\right) = \log A_t + \alpha \log\left(\frac{K_t}{L_t}\right) + \left(1-\alpha\right)\log H + u_t \tag{2}$$

We can also write Equation (2) as

$$y_t = a_t + \alpha k_t + \left(1-\alpha\right) H_t + u_t \tag{3}$$

where small-case letters y_t and k_t represent the natural logarithms of per capita output and capital stock. Equation (3) contains many desirable properties that provide a good approximation to the production possibilities of a real economy. Equation (3) satisfies the assumptions of constant returns to scale, constant factor shares and perfect competition.

Inclusion of human capital as an input in the production function is debated. Mankiw et al. (1992) justified its inclusion, both theoretically and empirically. However, Benhabib and Speigel (1994) and Islam (1995) found human capital as an insignificant determinant of output. We followed an alternative approach by incorporating human capital as a determinant of output through its effect on labour. Data on aggregate output, labour force and human capital are retrieved from the World Bank. Time series data on the physical capital stock are not available and was calculated through the perpetual inventory method (PIM). Steady-state value of the initial capital stock for the year 1980 is estimated through:

$$K_0 = \frac{1}{r+\delta} \Delta I_0$$

where K_0 is the productive capital stock in the initial year (1980). I_0 represents the amount of investment in the initial period, r is the average growth rate of total output, δ is the rate of depreciation which is taken as 5% for each year. The physical capital stock for the subsequent time periods was obtained through:

$$K_t = I_t + \left(1-\delta\right) K_{t-1} \tag{4}$$

where K_t is the capital stock available at time t, K_{t-1} is the capital stock left over from period $t-1$, δ is a constant depreciation rate and I_t is the investment or capital purchase at time t.

Human capital index is obtained on the basis of average years of schooling for the population aged 15 and above, and an assumed rate of return for primary, secondary and tertiary education as provided by Psacharopoulos' (1994) survey of wage equations. The annual data series on average years of schooling was interpolated from the quinquennial data series provided by Barro and Lee (2013). Using these inputs, the human capital per worker is constructed as follows:

$$H_t = e^{\varnothing(E_t)}$$

where H_t is the human capital at time t, E_t is the average years of schooling and $\varnothing(E_t)$ is a piecewise linear function, with a zero intercept and a slope of 0.13 through the 4th year of education, 0.10 for the next 4 years and 0.07 for education beyond the 8th year. As regards the last ingredient required by Equation (3), namely α, the share of capital input is taken to be 0.3%, following the empirical literature on the decomposition of output growth (Baier et al., 2006; Gollin, 2002).[1] Whereas the share of labour in total output is assumed to be 0.7%. With this approach, the TFP is approximated in the Hicks-neutral case by

$$a_t \cong y_t - \alpha^* k_t - (1-\alpha)^* h_t \tag{5}$$

TFP, as given in Equation (5) by a_t, is a Solow residual that captures those changes in output, which are not accounted for changes in measured inputs. With this disaggregation, the next step is to identify significant determinants of TFP as given in the following section.

Econometric Model of Total Factor Productivity

We started with the following general formulation (6) to establish the relationship between the TFP as estimated from Equation (5) and its determinants:

$$\text{TFP} = f(\text{CPI}, \text{FDI}, \text{GDCF}, \text{PC}, \text{EXP}, \text{IMP}, \text{GC}, \text{DR}) \tag{6}$$

Specifically, the empirical equation can be written as:

$$\text{TFP}_t = \beta_0 + \beta_1\text{CPI}_t + \beta_2\text{FDI}_t + \beta_3\text{GDFC}_t + \beta_4\text{PC}_t + \beta_5\text{EXP}_t + \beta_6\text{IMP}_t + \beta_7\text{GC}_t + \beta_8\text{DR}_t + \upsilon_t \tag{7}$$

where TFP is the total factor productivity, and CPI is the consumer price index representing price stability. FDI, EXP and IMP are the foreign direct investment, exports and imports, respectively; representing how integrated India is with the rest of the world. GC is the government consumption, GDFC is gross domestic capital formation, PC is the private credit issued by financial institutions and DR stands for drought, which is a proxy of natural calamities. These variables are explained in a brief detail in Appendix 1. υ_t represents the regression error term assumed to be normally distributed with constant variance.

Autoregressive Distributed Lag Approach of Cointegration

To examine the impact of underlying variables on TFP, various econometric techniques can be resorted to. These include cointegration tests developed by Engle and Granger (1987), Johansen (1988, 1991), and Johansen and Juselius (1990). However, these tests are very sensitive to the stationarity property of the data and sample size. Johansen cointegration test requires that all the variables be integrated of order one, that is, $I(1)$ and, therefore, cannot be applied directly if the variables are of mixed order of integration, that is, $I(0)$ and $I(1)$, or all of them are not non-stationary.

To address these issues, we followed the ARDL approach developed by Pesaran and Shin (1999) and Pesaran et al. (2001). ARDL approach has gained considerable importance in the recent empirical exercises because of its various econometric advantages over other methods of cointegration. Unlike the other approaches, the ARDL approach performs better for both non-stationary time series as well as for time series with a mixed order of integration (Rasool et al., 2020). The ARDL approach chooses optimal lags of the dependent variable (p lags) and independent variables (q lags) to capture the data-generating process within general-to-specific modelling framework, which, in turn, gives the ARDL approach an advantage of mitigating the contemporaneous causation from the dependent to the independent variables that might cause biased estimates. Further, ARDL provides robust and super consistent estimates of the long-run coefficients in case of small samples, and therefore inferences are based on normal asymptotic theory. The ARDL approach corrects for the problems of serial correlation and endogeneity (Pesaran & Shin, 1999). However, one of the caveats of the ARDL model is that it underperforms when the data series is integrated of order 2, that is, $I(2)$. We specify the ARDL(p, q) model for TFP as follows:

$$\begin{aligned}\Delta TFP_t = {} & \beta_0 + \gamma_1 TFP_{t-1} + \gamma_2 CPI_{t-1} + \gamma_3 FDI_{t-1} + \gamma_4 GDFC_{t-1} + \gamma_5 PC_{t-1} + \gamma_6 EXP_{t-1} \\ & + \gamma_7 IMP_{t-1} + \gamma_8 GC_{t-1} + \gamma_9 DR_{t-1} + \sum_{i=1}^{p} \beta_{1i} \Delta TFP_{t-i} + \sum_{i=0}^{q} \beta_{2i}\, \Delta CPI_{t-i} \\ & + \sum_{i=0}^{q} \beta_{3i}\, \Delta FDI_{t-i} + \sum_{i=0}^{q} \beta_{4i}\, \Delta GDFC_{t-i} + \sum_{i=0}^{q} \beta_{5i}\, \Delta PC_{t-i} + \sum_{i=0}^{q} \beta_{6i}\, \Delta EXP_{t-i} \\ & + \sum_{i=0}^{q} \beta_{7i}\, \Delta IMP_{t-i} + \sum_{i=0}^{q} \beta_{8i}\, \Delta GC_{t-i} + \sum_{i=0}^{q} \beta_{9i}\, \Delta DR_{t-i} + \upsilon_t \end{aligned} \tag{8}$$

where Δ is the first difference operator, p and q is the optimal lag length, $\gamma_1,\gamma_2,\ldots,\gamma_9$ represent the long-run coefficients, while as $\beta_1,\beta_2,\ldots,\beta_9$ are the short-run coefficients. The selection of optimal lag length (p and q) is determined through various information criteria such as Akaike information criteria (AIC), Bayesian information criteria (BIC), R^2 and Hannan–Quinn (HQ). Before applying the ARDL model, the integration levels of all the variables must be checked. The standard augmented Dickey–Fuller (ADF) test is used for this purpose. The Bounds test based on F-statistic is used to test the null hypothesis of the non-existence of a long-run relationship or cointegration in Equation (8). Pesaran et al. (2001) reported two sets of critical values for any given significance level—one set of critical values (lower critical bound—LCB) assumes that all the variables are I(0); the other set (upper critical bound—UCB) assumes that all the variables are I(1). The (non)-existence of cointegration between the variables depends on LCB and UCB. The decision rule is that if all the variables are stationary, it is more appropriate to compare calculated F-statistic with LCB, while, if the variables follow a mixed order of integration, compare calculated F-statistic with UCB. We reject (accepted) the null hypothesis of no cointegration if the F-statistic is greater (lower) than upper (lower) critical bound, respectively. However, when the F-statistic falls between the two bounds, the cointegration test becomes inconclusive. If cointegration is established, then we proceed to estimate the error correction model (ECM) version of Equation (8) as given by:

$$\begin{aligned}\Delta TFP_t = {} & \beta_0 + \sum_{i=1}^{p} \beta_{1i}\, \Delta TFP_{t-i} + \sum_{i=0}^{p} \beta_{2i}\, \Delta CPI_{t-i} + \sum_{i=0}^{p} \beta_{3i}\, \Delta FDI_{t-i} + \sum_{i=0}^{p} \beta_{4i}\, \Delta GDFC_{t-i} \\ & + \sum_{i=0}^{p} \beta_{5i}\, \Delta PC_{t-i} + \sum_{i=0}^{p} \beta_{6i}\, \Delta EXP_{t-i} + \sum_{i=0}^{p} \beta_{7i}\, \Delta IMP_{t-i} + \sum_{i=0}^{p} \beta_{8i}\, \Delta GC_{t-i} \\ & + \sum_{i=0}^{p} \beta_{9i}\, \Delta DR_{t-i} + \gamma ECT_{t-1} + \upsilon_t \end{aligned}$$

where γ is the speed of adjustment towards long-run equilibrium after the occurrence of shock and ECT represents the error correction term derived from the long-run relationship as given in Equation (8).

III. Empirical Results and Discussions

Unit Root Tests

Before applying the ARDL model to assess the relationship between variables, the first step is to provide an overview of the data itself. Accordingly, we began our analysis by examining the statistical properties of the variables under consideration, which, in turn, would help to select the appropriate time series methodology. For that purpose, we employ standard ADF unit root test for all the variables both at levels and first difference. Unit root tests on the first differences of all the variables will suffice to understand the nature of the data series. The results of the ADF test are presented in Tables 1 and 2.

In Table 1, the column heading of Prob. represents the probability-value (p-value) of ADF test for each variable at levels. The test maintains the null hypothesis of a unit root against the alternative of stationarity. Since the p-value of TFP is 0.000, we reject the null hypothesis that TFP contains a unit root at the *level*. At the same time, p-value associated with other regressors is greater than any conventional level of significance. Accordingly, we fail to reject the null hypothesis that regressors have a unit root. Therefore, Table 1 shows that the data set is a mixture of I(0) and I(1) processes, which is the precise situation where ARDL modelling and Bounds testing are applicable. However, the ARDL model has a limitation of underperforming at second-order integration of variables, and, we, therefore, applied ADF at the first difference of each variable as reported in Table 2.

Table 1. Unit Root Test at Levels (ADF).

Variables	Prob.	Lag	Max Lag	Obs.
TFP	0.0000	0	8	35
CPI	0.9999	5	8	31
FDI	0.5605	0	8	36
GDCF	0.7995	0	8	36
GC	0.5376	0	8	36
PC	0.8735	2	8	34
IMP	0.7779	0	8	36
EXP	0.8866	0	8	36

Source: The authors.

Note: TFP = Total factor productivity; CPI = consumer price index; FDI = foreign direct investment; GDFC = gross domestic capital formation; GC = government consumption; PC = private credit; IMP = ratio of imports to GDP; and EXP = ratio of exports to GDP.

Table 2. Unit Root Test at First Difference (ADF).

variables	Prob.	Lag	Max Lag	Obs.
D(TFP)	0.0003	2	7	32
D(CPI)	0.0214	4	8	31
D(FDI)	0.0000	0	8	35
D(GDCF)	0.0007	0	8	35
D(GC)	0.0055	0	8	35
D(PC)	0.0549	1	8	34
D(IMP)	0.0030	0	8	35
D(EXP)	0.0008	0	8	35

Source: The authors.

Note: TFP = Total factor productivity; CPI = consumer price index; FDI = foreign direct investment; GDFC = gross domestic capital formation; GC = government consumption; PC = private credit; IMP = ratio of imports to GDP; and EXP = ratio of exports to GDP.

Table 3. Correlation Matrix.

Variables	TFP	CPI	FDI	GDCF	GC	PC	IMP	EXP
TFP	1.00							
CPI	0.17	1.00						
FDI	0.07	0.77	1.00					
GDCF	0.20	0.78	0.58	1.00				
GC	–0.29	–0.71	–0.64	–0.73	1.00			
PC	0.19	0.72	0.68	0.59	–0.75	1.00		
IMP	0.17	0.68	0.59	0.69	–0.71	0.49	1.00	
EXP	0.18	0.90	0.68	0.71	–0.78	0.69	0.70	1.00

Source: The authors.

Note: TFP = Total factor productivity; CPI = consumer price index; FDI = foreign direct investment; GDFC = gross domestic capital formation; GC = government consumption; PC = private credit; IMP = ratio of imports to GDP; and EXP = ratio of exports to GDP.

Variance inflation factors for TFP [1.70], CPI [1.91], FDI [2.25], GDCF [4.95], GC [1.49], PC [5.87], IMP [4.02] and EXP [5.77].

Table 2 shows that the null hypothesis that data series is I(2) is rejected against the I(1) alternative at the 1% and 5% significance levels. This ensures that the application of ARDL model will be suitable to proceed with the long-run relationship between the variables under investigation. However, before proceeding for the estimation of the long-run relationship between the variables, Table A1 presents the summary statistics of each variable given in the following section.

Descriptive Statistics

From Table A1, the *p*-value associated with the normality test of Jarque–Bera reveals that the normality assumption is maintained for most of the variables. The mean value of the variables under consideration is found to be greater than their respective standard deviations. It shows that all the variables are stable over the sample period. Following the summary statistics, we presented the correlation among the variables in Table 3.

Correlation matrix provides information for detecting any multicollinearity between the variables. However, as per the results presented in Table 3, the correlation coefficients for each pair of variables is less than 1. Further, the test of Variance Inflation Factors[2] provides no evidence of collinearity among the variables. Therefore, multicollinearity is not a serious concern here, and we take this point as encouraging to proceed for further investigations.

Cointegration Test

In what follows, we proceed for the estimation of ARDL model that explains that TFP is determined by a vector of variables, including FDI, CPI, GDCF, GC, IMP, EXP, PC and DR. However, it is feasible to proceed to the ARDL model only when the cointegration test reveals the existence of a long-run relationship between the variables. Accordingly, we applied the Bounds test based on *F*-statistic to examine the presence of a long-run relationship among the variables under consideration. In the Bounds test approach, the null hypothesis of no cointegration among the variables (H_0: $\gamma_0=\gamma_1=\gamma_2,\ldots,=\gamma_9 = 0$) is tested against the alternative hypothesis that there is cointegration among the variables (H_1: H_0 is not true). Table 4 reports the significance of F-statistic on the joint significance of the long-run coefficients.

The appropriate lag length for each variable is determined on the basis of the Schwartz Bayesian Criterion (SBC). As indicated in Table 4, the value of F-statistics (4.95) is greater than the UCB value, which is 4.26 at all significance levels. It implies the rejection of the null hypothesis of no cointegration among the variables. Therefore, the Bounds test confirms that the variables under consideration have a long-run relationship. After validation of the existence of cointegration among the variables, we proceed to estimate the long-run and short-run estimates of the effect of regressors on TFP in India. Table 5 presents the long-run estimates of ARDL model based on the SBC.

Table 4. Significance of *F*-test for Cointegration.

Model	*F*-statistic	Significance Level (%)	LCB	UCB	Decision
TFP = *f*(FDI,CPI, GDCF, GC, IMP, EXP, PC, DR)	4.9562*	10	2.037	3.13	Cointegration
		5	2.32	3.5	
		1	2.96	4.26	

Source: The authors.

Note: TFP = Total factor productivity; CPI = consumer price index; FDI = foreign direct investment; GDFC = gross domestic capital formation; GC = government consumption; PC = private credit; IMP = ratio of imports to GDP; EXP = ratio of exports to GDP; and DR = drought. LCB and UCB denote lower critical bound and upper critical bound values, respectively.

H_0: There is no long-run relationship.

* Denotes rejection of the null hypothesis of no cointegration at all significance level.

Table 5. Long-run Estimates from the ARDL Model (dependent variable is TFP).

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
CPI	0.0005	0.0002	2.3455	0.0343
PC	0.0018	0.0009	2.0492	0.0597
FDI	0.0117	0.0084	1.3794	0.1894
EXP	–1.1382	0.4475	–2.5437	0.0234
IMP	0.2563	0.2551	1.0045	0.3322
GDCF	0.1036	0.2936	0.3529	0.7294
GC	–1.6473	0.5482	–3.0051	0.0095
DR	–0.0140	0.0059	–2.3846	0.0318
Constant	0.2077	0.0766	2.7115	0.0169

Source: The authors.

Notes: TFP = Total factor productivity; CPI = consumer price index; FDI = foreign direct investment; GDFC = gross domestic capital formation; GC = government consumption; PC = private credit; IMP = ratio of imports to GDP; EXP = ratio of exports to GDP; and DR = drought.

Analysis of the Long-run and Short-run Relationship

Table 5 reveals that most of the variables are statistically significant and have expected signs. More precisely, inflation (CPI) has a significant and positive but negligible impact on TFP in the long run. These results suggest that inflation in India has not reached a threshold level beyond which inflation affects growth negatively. We note that our results are in line with the study of Khan and Sinhadji (2001), which estimated the threshold level of inflation for a panel of 140 countries over the period from 1960 to 1998. The study argued that inflation rate beyond 11%–12% only exerts a negative impact on growth in developing countries. Ghosh and Phillips (1998), while investigating non-linear inflation–growth nexus also report similar results. Private credit (PC) also had a similar effect. Arizal et al. (2009), while investigating the impact of financial development on TFP growth using cross-country regressions found that deepening of PC promotes productivity growth in developing countries by lowering financial constraints. The small impact of PC in the present study may be attributed to the underdevelopment of financial institutions in India.

Economic openness contributes to productivity growth through a number of channels. Prominent among them is the technological diffusion from developed to developing countries, like India. In our study, foreign capital and imports show a similar pattern, while exports do not. Foreign capital (FDI) shows a positive but insignificant impact on TFP during the sample period. Foreign capital, which is considered highly important for developing and capital-scarce countries like India, seems less likely to be an agent of productivity. Though it affects TFP positively, the overall impact is quite low. It adds only 0.01 units to the TFP with every one unit increase in foreign capital flows. The possible reason for the insignificance of FDI may be what Hermes and Lensink (2003) argued—the impact of FDI on productivity growth is contingent upon the level of financial development in a host country. This possibility is confirmed by the negligible but significant impact of financial development on TFP in the long run.

The negative and significant coefficient of exports indicates that TFP diminishes by 1.13 units per incremental unit of exports. This is, however, contrary to the conventional belief that exports increase productivity through learning by doing and/or exporting hypothesis. With regard to the negative impact of exports on TFP growth, our results lend support for the studies of Behera and Yadav (2019), Choi and Baek (2017), Kim et al. (2009), Kim and Lin (2009), and Trejos and Barboza (2015). These studies provide a number of channels through which exports affect TFP negatively. Behera and Yadav (2019) concluded that the long-run negative impact of exports on TFP could be explained by the fact that manufactured goods, especially low-level engineering products and gems and jewellery, dominate the export basket of India. India's manufacturing exports account for a low share in the world, mainly because of the low value and semi-skilled nature of these products. Hence, the performance of India's exports cannot be regarded as phenomenal. The studies by Kim and Lin (2009) and Trejos and Barboza (2015) found that the impact of exports on productivity is conditional on the level of economic development, with trade having a positive effect on productivity across the developed countries, but it can have a negative impact across developing countries. On the other hand, Choi and Baek (2017) argued that Indian exports are dominated by primary industries such as unrefined (15% of total exports), gems and jewellery (13%), agricultural products (10%), cotton (10%) and cotton-based ready-made garments and accessories (6%). Such a composition of exports exerts a negative impact on TFP, which is primarily driven by technological change.

Imports (IMP) and domestic capital (GDFC) have a positive but statistically insignificant impact on productivity in the Indian scenario, confirming positive spillovers. The coefficient estimate of imports indicates that TFP improves by 0.25 units with every one unit increase in imports. Kim et al. (2009) concluded that imports promote TFP through increased competition among domestic firms, owing to imports of consumer goods and technological diffusion embodied in imports from developed countries. Similarly, per unit increment in capital formation (GDCF) pushes TFP up by 0.10 units. The positive coefficient of GDCF suggests one unit increase of investment is associated with a 0.10 unit increase in TFP. Overall, these results show that TFP is predominantly impacted by imports, followed by capital formation.

Government consumption (GC) has a negative and statistically significant impact on TFP. The estimated effect of GC on TFP indicates that TFP declines by 1.64 units per unit of incremental GC. The literature is divided on this issue. On the one hand, numerous past studies have found that over the long run, TFP growth is harmed by unproductive GC. On the other hand, another strand of research highlighted the positive impact of GC on TFP growth (Ram, 1986). Our results are in line with Easterly and Rebelo (1993) and Chandra (2004). After examining the impact of GC on TFP growth over the period from 1950 to 1996 in India, Chandra (2004) concluded that government consumption is not an engine of growth both in the short run and in the long-run. As expected, the impact of natural calamities as proxied by drought is found to be negative and significant with the coefficient estimate of −0.01 units. The impact of natural calamities, in general, is felt across all the sectors of the economy, but its effect on the agricultural sector is huge. Since India has significantly moved away from an agrarian economy to secondary and tertiary sectors, the impact of natural calamities has been found to be minimal.

Table 6 reports the estimates of short-run coefficients of the effects of regressors on TFP. The optimum lag length for the error correction representation of ARDL model is determined by SBC. The coefficient of the error correction term of the ARDL TFP model is found to be negative and statistically significant at all levels. This result ensures that 174%[3] disequilibrium in the TFP is corrected in the next period after a short-run deviation from long-run equilibrium in the previous period.

The significant coefficient (0.75 units) of TFP at lag 1 indicates its mean reversion property after one period lag, following a shock in the system. As shown in Table 5, FDI is found to be insignificant with a positive impact on TFP. However, Table 6 shows that FDI positively impacts TFP after one period lag with a coefficient estimate of 0.02 and is found to be statistically significant, albeit at the 8% level. Similarly, the long-run insignificant coefficient on gross capital formation turns out to be statistically significant at the 1% level with an estimate of 1.25 units. It indicates that one unit increase in gross fixed capital formation tends to increase TFP by 1.25 units in the short run. GC, however, impacts TFP negatively in the short run as well as in the long run (see Tables 5 and 6). In the short run, exports emerged to be insignificant but significant with one period of time lag. The positive impact of exports on TFP reveals macroeconomic stability or strong fundamentals of the Indian economy, as highlighted by numerous past studies. The impact of CPI and credit to the private sector is found to be negligible though significant in the short run as well as in the long run. While these results may be influenced by dependence, variance and covariance properties of the regression error term, it is common practice to perform certain residual diagnostic tests to obtain robust results.

Goodness of Fit and Diagnostic Checks

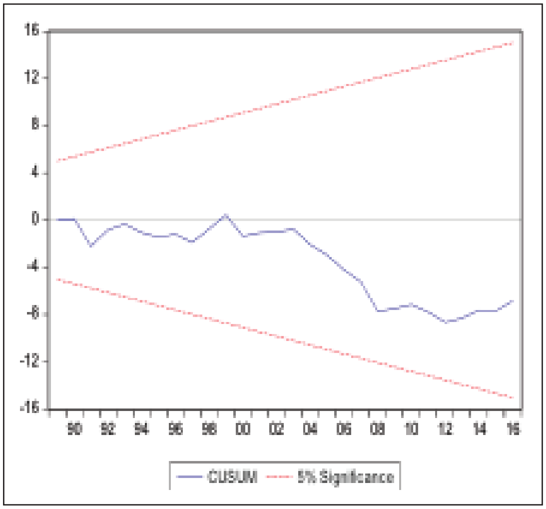
The measures of goodness of fit for the estimated model as indicated by adjusted-R^2 and Durbin–Watson test are satisfactory (Table 6). It indicates that the estimated ARDL–ECM model has a predictive power of 89%, which means that the model explains about 90% of the variation in the data. On the other hand, the value of Durbin–Watson statistic is found to be 1.70, which means that the model is free from the autocorrelation problem. Table A2 presents the residual diagnostic tests of serial correlation and heteroscedasticity for ARDL TFP model. The p-value associated with Breusch–Godfrey LM is found to be 0.24 under the null hypothesis of serially uncorrelated residuals. We, therefore, fail to reject the null hypothesis and conclude that there is no serial correlation. However, under the null hypothesis of homoscedasticity of residuals, the *p*-value associated with Breusch–Pagan–Godfrey test is found to be 0.75. Therefore, we also fail to reject the null hypothesis and conclude that residuals are homoscedastic. We can, therefore, conclude that the results of our study are robust and consistent.

Table 6. Short-run Estimates from ECM (dependent variable is TFP).

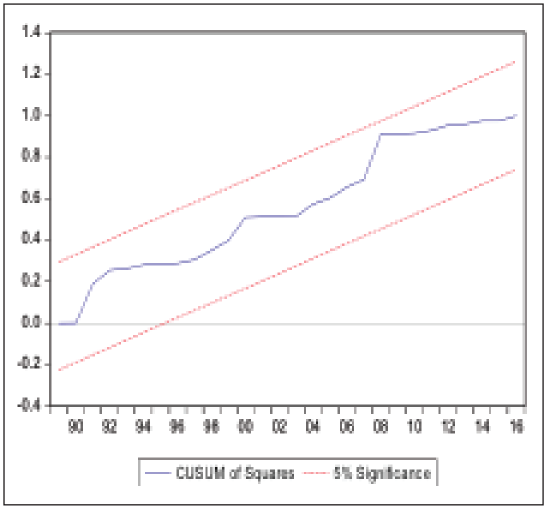
Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
D(TFP(–1))	0.753	0.230	3.279	0.006
D(FDI)	0.000	0.010	0.003	0.998
D(FDI(–1))	0.026	0.014	1.838	0.087
D(GDCF)	1.252	0.449	2.787	0.015
D(GC)	–2.005	0.969	–2.070	0.058
D(GC(–1))	3.862	0.989	3.905	0.002
D(IMP)	–0.305	0.358	–0.853	0.408
D(IMP(–1))	–1.117	0.421	–2.651	0.019
D(EXP)	0.592	0.488	1.213	0.245
D(EXP(–1))	2.675	0.831	3.218	0.006
D(CPI)	0.001	0.000	2.243	0.042
D(PC)	0.003	0.002	1.900	0.078
D(DR)	–0.024	0.011	–2.236	0.042
CointEq(–1)	–1.744	0.312	–5.584	0.000
R^2	0.89	Mean dependent variance	0.0008	
Adjusted R^2	0.82	S.D. dependent variance	0.028	
S.E. of regression	0.012	Akaike info criterion	–5.754	
Sum squared residual	0.004	Schwarz criterion	–5.215	
Log likelihood	109.82	Hannan–Quinn criterion	–5.570	
Durbin–Watson statistics	1.70			

Source: The authors.

Notes: TFP = Total factor productivity; CPI = consumer price index; FDI = foreign direct investment; GDFC = gross domestic capital formation; GC = government consumption; PC = private credit; IMP = ratio of imports to GDP; EXP = ratio of exports to GDP; and DR = drought.



Plot of Cumulative Sum of Recursive Residuals



Plot of Cumulative Sum of Squares of Recursive Residuals

Figure 1. CUSUM Tests.
Source: The authors.
Note: Under the null hypothesis of constant coefficients, values of a sequence of sums, or sums of squares, of recursive residuals outside 5% critical values (red lines in figure) suggest a structural change in the model.

In order to test the stability of the short-run and long-run coefficients estimated by the ARDL–TFP model, we use cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) of recursive residuals computed iteratively from nested subsamples of the data, which are presented in Figure 1, respectively. The figure indicates that the coefficients of the ECM are stable over the sample period because plots of CUSUM and CUSUMSQ statistics remain within the 5% critical bounds. Overall, Table A2 and Figure 1 show that the model has desirable statistical and theoretical properties and can be used for policy analysis.

IV. Conclusion and Policy Implications

The present study investigated the short-run and long-run impacts of price stability, economic integration, government size, capital formation, financial development, and natural calamities on the TFP in the case of India over the sample period from 1980 to 2016. Specifically, this was achieved in two stages. In the first, we measure growth in TFP within a growth accounting framework. Then, using the ARDL model, we studied the potential relation and significance of various determinants of TFP.

The statistical results from the regression analysis confirmed the presence of equilibrium correcting relationship between TFP and its various determinants. It is found that inflation and financial development have a positive and statistically significant impact on TFP in the long run. FDI, imports, and capital formation are found to have a positive but insignificant impact on TFP. On the other hand, exports, government size, and natural calamities have a statistically negative impact on the TFP. Our findings point out these estimates as to be robust than the previous studies and can be applied reliably for further

TFP research. The statistical results of our study have some policy implications for identifying and understanding what actually drives TFP. In order to accelerate TFP, government and policymakers need to improve financial access to the private sector while ensuring price stability, as price stability has a positive effect on TFP. A strong financial sector is able to finance increased real domestic investment and absorb adverse shocks in the economy. Moreover, policymakers need to design and implement policies for enhancing economic integration in the global economy, in order to benefit from foreign investment flows, which bring in new technology. In order to maintain sustainable growth, policymakers should also focus on achieving phenomenal export of high-value products rather than low-value manufactured items. Finally, gross capital formation is another variable that plays a positive role in the long-term achievement of sustainable TFP growth. One area for future TFP research is to accommodate potential structural breaks in the underlying variables, which lower the statistical power of econometric exercise conducted in the present study.

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Notes

1 This is within 0.25 to 0.35 range of Gollin's (2002) cross-country estimates.
2 Variance Inflation Factors (VIF) is a method of measuring the degree of collinearity between the explanatory variables in a model. Vittinghoff et al. (2011) considers VIF value of less than 10 as acceptable to justify inclusion of a given explanatory variable in the model.
3 Coefficient on speed of adjustment term (here −1.74) is lower than −1 but higher than −2. This suggests that the disequilibrium between shocks and the long-run equilibrium is reduced in less than 1 year.

Appendix 1

Variables and source of data: Theoretically, there are a number of factors that affect the total factor productivity (TFP). This research only explores the relative impact of significant factors, and a brief description of these factors is given below.

Price stability: Inflation, as proxied by changes in the consumer price index, is used as an indicator of macroeconomic stability. Inflation has the potential to affect productivity in multiple ways. It may reduce the efficiency gains by hindering the transmission of information of the price system through the increased variance of relative prices. It may also shift the production process to labour-intensive techniques due to rising energy prices. Further, reduction in capital per worker due to increasing rents of capital services may also onstrain productivity.

Size of government: Size of government is measured through the proxy of general government consumption expenditure as a share of GDP. The government may finance its expenditure through various distortionary taxes. Higher government consumption to GDP ratio requires higher taxation of individual households and firms to finance government expenditure. This, in turn, affects TFP negatively by reducing household savings and firm profits otherwise available for productive investments.

Economic integration: Economic integration means allowing goods and capital to flow across the national geographical boundaries. Opening up trade, especially with developed countries, positively affects productivity by transferring technical know-how not locally available, which Solow regards the single most crucial factor for raising TFP. Productivity may be increased through technological imitation without bearing R&D costs. In a similar vein, the foreign flow of capital, especially green-field investments, brings in new technology, which enhances the factor productivity. Since economists' give mixed views on the effects of trade openness (imports and exports divided by GDP) on productivity, we included disaggregated measures of trade openness. Trade openness is measured through the ratio of import to GDP and ratio of export to GDP, and capital openness is measured through the net inflow of FDI.

Gross domestic capital formation: It is an addition made to the productive capacity of an economy. In reality, capital formation is a diversion of a chunk of currently available consumable resources back to the production process to expand output-producing capacity in the future. From relieving the underdeveloped and developing countries out of the clinches of adverse balance of payment conditions and foreign debts to the promotion of technical efficiency through enabling large-scale production and market enlargement through the creation of economic and social overheads, capital formation establishes a range of routes to economic prosperity. Indian capital formation is primarily driven by private sector investments, followed by household and public investments. These three sectors contributed 37%, 32% and 26%, respectively, in 2011–2015 five year plan. In 2010, capital formation stood at 36% of GDP and has fallen to 27% in 2016 (World Bank), which is far below the average of economically prosperous countries like China, where it stood at 50% in the same period.

Financial development: Financial deepening plays a crucial role in enhancing TFP by raising capital per worker, especially in capital-scarce developing countries. Efficient and sound financial sector effectively removes the capital constraints by pumping investments through the promotion of higher savings and there efficient channelisation. By channelising savings into productive projects, developed financial institutions positively impact rates of economic growth, physical capital stock and TFP. Development of the financial sector is effectively indicated by loans granted to households and firms by banking and non-banking financial companies, precisely known as private credit. We use the ratio of domestic credit to the private sector and GDP as a proxy for financial development.

Natural calamities: Natural calamities also significantly influence factor productivity, particularly in agrarian economies like India. Frequent droughts and rainfall deficits affect agriculture, which, in turn, have an impact on the overall economy. In this study, we have used the frequency of droughts as a proxy for natural calamities. A dummy variable was used to measure the effect of drought, taking a value of 1 for a year affected by drought, and 0 otherwise.

Table A1. Descriptive Statistics.

Statistics	TFP	CPI	FDI	GDCF	GC	PC	EMP	EXP
Mean	0.03	58.01	0.90	0.26	0.12	33.81	0.16	0.14
Median	0.03	50.91	0.63	0.24	0.12	26.55	0.14	0.11
Maximum	0.07	154.95	3.66	0.35	0.14	52.44	0.31	0.25
Minimum	–0.02	11.38	0.00	0.20	0.10	21.51	0.07	0.06
Std. Dev.	0.02	41.79	0.92	0.05	0.01	11.78	0.08	0.07
Skewness	–0.52	0.90	1.05	0.54	–0.13	0.64	0.53	0.40
Kurtosis	3.14	2.77	3.54	1.66	2.07	1.64	1.87	1.53
Jarque–Bera	1.68	4.90	7.04	4.43	1.39	5.19	3.61	4.20
p-Value	0.43	0.09	0.03	0.11	0.50	0.07	0.16	0.12

Source: The authors.

Note: TFP = Total factor productivity; CPI = consumer price index; FDI = foreign direct investment; GDFC = gross domestic capital formation; GC = government consumption; PC = private credit; IMP = ratio of imports to GDP; EXP = ratio of exports to GDP.

Table A2. Residual Diagnostic Checks.

Test	*F*-statistic	*p*-Value
Breusch–Godfrey serial correlation LM test	1.604523	0.2413
ARCH heteroscedasticity test	0.288077	0.7518

Source: The authors.

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