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Total factor productivity in Indian agriculture: An exploratory analysis based on literature review

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ABSTRACT

An attempt has been made to analyze the literature on Total Factor Productivity analysis in the context of Indian agriculture without going much deeper into its empirical analysis and estimation. Among the vast analytical themes possible on Indian agriculture, this study has focused upon the literature pertaining to the contribution of the non-conventional factors such as skills and technical know-how, fertilizers, High Yielding Varieties, etc. in explaining the shifts in agricultural production which are condensed to compose the concept of total factor productivity. The studies on total factor productivity in the Indian context are neither exhaustive nor limited but there is considerable scope for more detailed investigations into the various dimensions of productivity measurement and policy analysis. It can be noticed throughout the present discussion that there are a good number of thought-provoking issues associated with Total Factor Productivity but evidences are conflicting, sometimes controversial and subjected to further detailed investigation.

Key words: Agricultural economics, Agricultural productivity, Production function, Productivity measurement, Total factor productivity.

An analysis of measurements and empirical inferences pertaining to Productivity in general and agricultural productivity in particular has certain critical dimensions ranging from conceptual and methodological to data related issues which are not uniform and homogenous at both aggregated and disaggregated levels. In particular, the critical and important dimensions pertaining to empirical analysis and estimation of agricultural productivity have been an unending debate owing to cross-section of frameworks and measurement of variables. However, there is a considerable amount of consensus on broad measurement depending upon the kind of application that is undertaken for analysis. Though the study of productivity is not specifically related to agriculture, the fundamental views of various methods of analysis have given rise to different conclusions based on the heterogeneity that are prevalent in the information and in particular the context under consideration. A seminal work by Solow (1957) and subsequently many others1 have exhaustively developed the fundamental literature for empirical analysis on methodological and estimation techniques. Productivity can be analyzed in terms of both total and partial factor measures and the estimation can well vary across the sub-sectors and factor-use.

An attempt is made here to analyze the literature on productivity analysis in the context of Indian agriculture without going much deeper into empirical analysis and estimation. While the population growth, urbanization, and modernization continue to take place across space and time in India, the economy still moves on technical and social dualistic pattern built on urban as well as rural lifestyles and also continues to maintain a simultaneous co-existence of both traditional economic occupations and modern technology-driven industrial and service sectors. Agriculture sector is the primary a traditional source of employment for majority of Indian population, though its share in employment has been declining. This is not to deny that modernization has not occurred in the agriculture sector, but taken as a whole, still Indian Agriculture is not technologically advanced.

It has been observed that the aggregate production function in Indian agricultural sector might not have shifted much despite the consistently increasing Agricultural Gross Domestic Product (AGDP). Such an observation might put greater emphasis on the role of factor inputs and their respective productivities in explaining AGDP. These observations provide the rationale for an analysis devoted on understanding partial measures of agricultural productivity, *viz*. land, labour and capital productivities.

While the partial factor productivities, which indicate the variations in agricultural output due to conventional factors such as land, labour and capital, play an important role in understanding the dynamics of Indian

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agricultural sector in terms of output growth, the non-conventional factors also equally play a predominant role in explaining agricultural growth. The contribution of the non-conventional factors such as skills and technical know-how, fertilizer, High Yielding Varieties, etc. in explaining the shifts in agricultural production is condensed to compose the concept of Total Factor Productivity (TFP).[2]

The rest of the paper is organized as follows. Section II deals with analysis of studies that can be unearthed for discovering various dimensions of issues which are relevant for understanding the present state of agriculture from TFP point of view and, Section III discusses certain related issues to TFP analysis and Indian agriculture, while Section IV derives broad conclusions which are relevant for further research and analysis in the context of Indian agriculture.

REVIEW AND ANALYSIS

Total Factor Productivity as a concept examines the quantum of change in output not accounted for by changes in the conventional inputs such as land, labour and capital. The unexplained variation in the output after accounting for changes in the output due to conventional factors in the estimation of the production function represents TFP.[3] This residual nature of TFP has been imbibed in the methodological frameworks in which TFP has been analyzed up till now and the approaches to estimation of TFP can be classified into three types[4], namely, index-number method, growth accounting5 method and econometric methods.

The role of TFP in examining the trends, behaviour and nature of productivity changes across crops and regions cannot be more pronounced than in the case of Indian agriculture. While elementary statistics show that the share of Agriculture has been declining in both national income and total employment, changes in agricultural activities still have predominant effects on the aggregate economy. This predominance can be noted in the facts that agro sector has a majority share in employment, remains a major supplier of goods, shapes the rural socio-economic development, and, affects food inflation and nutritional adequacy, and, food security among others. In order to better appreciate the significance of agriculture for the particular objective of rural development and for the larger policy-aim of national economic development, it is imperative to understand the ways in which TFP has evolved over time and the factors determining it. The analysis of TFP not only helps to understand the macroeconomic logic behind the observed variations in agricultural output, but also motivates an understanding of several issues pertaining to agriculture such as agricultural production risks, profitability, rate of return on agro-investments, agro-labour market dynamics and in particular the process of wage rate determination under various factor market structure. It also has an important bearing on the policies and interventions at various levels of Governments for achieving a steady state of development of agricultural sector.

A recurrent research problem observed in the discourses on agricultural productivity across the academic landscape has been to associate the TFP growth to its various determinants. The residual nature of the TFP implies the complexity inherent in locating the sources of total productivity and hence poses an important challenge to any researcher in this area. The theoretical apparatus and the empirical framework including the data availability, within which the sources of TFP are modelled, critically affect the results reached by various studies. Indian agriculture posits special problems in terms of availability of data, variations in ground-water levels and precipitation rates, irrigation infrastructure, soil fertility, distribution of rainfall, government policy, etc. for proper estimation of productivities in general.

TFP analysis has therefore been a complex area of research in the Indian context. Methodology has been an important differentiating factor between various studies and differences in time periods, framework of analysis, variables used, etc. are key factors determining the conclusions reached. The results of various researches remain inconclusive regarding the behavioural characteristics of residual total productivity in Indian agriculture since Green revolution and, after the economic reforms, only limited evidences were found regarding a detailed analysis of the nature, behaviour and determinants of TFP at aggregate level. The following critical empirical facts are arranged on TFP to give comprehensive and analytical views and facts regarding Indian agriculture so as to arrive at some broad issues and reflections which are important for the Indian agriculture.

The landmark study that introduced methodological innovations which were to redefine the ways in which productivity analysis was to be undertaken at an aggregate level, stands due to Solow (1957). Though this work is not particularly relevant for agriculture but probably this study is marked as a fundamental shift in the approach towards measuring and analyzing productivity behaviour holistically. The author undertook a comprehensive analysis of the technological progress of whole of the U.S. economy and used the growth accounting framework to analyze how technical change had contributed to the total output. The time period of the study was from 1909 up to 1949. He defined residual total factor productivity as change in the technological parameter in the aggregate production function. Solow used the growth equation method to disintegrate technical change in the U.S. economy from movements over the production function by employing a Cobb-Douglas framework. The technical change parameter represented all the factors that could have changed the output over and above the changes in conventional factor quantities accounted for

by the production function. The assumption of perfectly competitive factor markets was utilized to segregate the shifts in the aggregate production function from movements over it but the possibility of extending that framework to monopolistic factor markets was also examined theoretically, though not utilized for empirical work. The study found that technical change parameter did not change much and hovered roughly constantly around a fixed mean with more or less random fluctuations. Some evidence of an increase in the rate of technical change was found around the year 1930. The author examined various forms of production functions including the Cobb-Douglas, semi-logarithmic and hyperbolic functions and found that Cobb-Douglas and semi-logarithmic functions performed relatively better than others in explaining the behaviour of aggregate output for the stated period. Lastly, it was found that Gross output per man hour had doubled, with 87.5 per cent of the increase attributable to technical change and the remaining I2.5 per cent to increased use of capital. The study however did not enter into the details of the determinants of the observed behaviour of productivity and further disaggregation into sectoral levels might have brought about still richer insights into the productivity trends for various sectors and their relative performance.

Another landmark study but with reference to Indian agriculture is due to Rosegrant and Evenson (1992) who undertook an analysis of TFP growth of major crops along with a focus on the sources of their productivity growth. The paper undertook a TFP analysis of 271 districts covering 13 states in India during 1956-87. The Tornquist-Theil index6 was used for constructing a TFP index. The TFP index consisted of an Output and an Input index and the output index included five major crops and ten minor crops. The index that was employed warranted the use of prices for both output and input aggregation. The study used farm prices for aggregation of output and farm rental prices for aggregation of inputs as weighting factors. Comparison of TFP index estimated for India was made with estimates available for Bangladesh and Pakistan from other studies. The study employed pooled data set at district level with fixed effects approach to analyze the determinants of TFP. These determinants included investments in research, extension, human capital, and infrastructure. They found that TFP grew steadily despite larger fluctuations due to weather variation, actually when agricultural growth itself was growing modestly. The study found that the main sources of productivity growth were public research, which accounted for more than thirty percent of variation in TFP, and, domestic and foreign research and extension responsible for around thirty-eight percent of TFP growth. The study is limited to a few crops not going into detail of certain important crops and also did not adopt an econometric approach to estimating TFP. Probably, price variations and absolute prices are not considered.

Dholakia and Dholakia (1993) estimated residual TFP growth for the period 1950-51 to 1988-89 for Indian agriculture and allied sector combined. The methodology involved constructing a residual measure of output growth by decomposing the total output growth into conventional input-based and TFP-based variations. The ratio of Output index to Input index produced the TFP index estimates. The use of factor incomes was made as relative weights for aggregation of inputs. The authors divided their study period based on green revolution years as the cutting point for classification namely the pre-green revolution period (1950-51 to 1966-61), the initial phase of green revolution (1966-67 to 1980-81), and the modernization phase (1980-81 to 1988-89). The actual growth of agricultural income as measured by Net Domestic Product (at 1980-81 prices) had been similar across all sub-periods in spite of the fact that the same is adjusted or not adjusted for weather conditions as measured by a dummy variable. The estimate of potential output growth for the entire period was arrived by log-linear method on the information obtained by all peak-outputs during the sample and the same was found to be 2.19 percent. The observed growth rate of income was compared accordingly. They noted that the growth of actual income was highest during the third phase and identified that the increasing modernization of agro-technology was considered as a key factor in explaining this trend. The authors used the neoclassical growth equation (such as in Solow 1957) to capture the growth in Agricultural income by modifying it to include capacity utilization and weather condition. The study extracted important observations about the manner in which input growth and technological growth explained the total agricultural output growth. A noteworthy aspect of this study was that it further decomposed the TFP growth into a relatively purer measure of individual variation in TFP that could be accounted separately for technical change, weather and capacity utilization. This was probably done to extract more meaningful information on technical progress that could have had major impact on variation in the TFP during the stated period. Had these individual variations not been split, it would have been very difficult to identify the impact of technical progress in the presence of combined variation with weather and capacity utilization. The authors found that the TFP growth accounted for dominant variations of output in the modernization phase whereas the earlier periods were characterized by factor-use driven growth. The study noted that around seventy-five percent of output growth was captured by TFP growth in the third phase between 1980-81 and 1988-89 and in absolute terms 1.82 percentage points output growth was due to TFP change. They found an increasing trend in TFP growth over the whole selected period. The determinants of TFP were analyzed using a simultaneous equation model and a Modern Inputs Index (MII) was constructed to disentangle the inter-correlated relationship between Irrigation, Fertilizer use and HYV seeds

by using Principle Component method. The elasticity of TFP index to MII was found to be 0.21 percentage point for the whole period. The analysis revealed that modernization in agriculture including the usage of modern inputs had significantly contributed to TFP growth. An important dimension for policy-making that emerges from this study is the critical bearing of investments in modern inputs such as HYV, Fertilizers, more sophisticated irrigation infrastructure, etc. for enabling productivity growth. The study views the analysis of productivity from a macro point of view but does not go into detail of regional specific dimensions which could have been very crucial for decentralized and regional planning.

Rosegrant and Evenson (1995) updated the framework utilized previously (Rosegrant and Evenson, 1992) and focused more exhaustively on estimating the rate of return on public and private investments in Indian agriculture sector for the period 1957 up to 1986 for 271 districts covering thirteen states. In order to examine the rate of return on agro-investments particularly in public research, the study estimated TFP index using the Tornquist-Theil measure. The ratio of the Output index to Input index yielded the TFP index. The authors used five major and fifteen minor crops in order to calculate the Output index while employing farm prices of these crops as weighting factors. The inputs included irrigated land, unirrigated land, tube-well irrigation capital, human labor, animal labor, tractors, and fertilizers while using farm rental prices to aggregate the inputs. The analysis of determinants of TFP was done by using panel regression method with fixed-effects approach. The total time period was decomposed into three parts *viz*. 1956-66, roughly corresponding to the pre-green revolution period; 1967-77, the green revolution period; and 1978-87, the post-green revolution period. The factors modeled as determinants of TFP growth were rural infrastructure development, the ratio of net irrigated area to net cropped area, the ratio of farm wages to annual earnings of non-farm workers, the stock of research, the proportion of area under modern crop varieties, rainfall, domestic and foreign patented inventions of agricultural implements among others, with appropriate changes in their form. TFP growth was decomposed according to the above factors. The study found that TFP growth was significantly influenced by investments in the areas such as research, extension, markets and irrigation. Finally, the study also estimated the rate of return on agro-productivity enhancing investments. It was found that the marginal rate of return on public research was very high, well above seventy percent, and that on public extension at around sixty-one percent, during the entire period. The private sector research contributed much less than the public sector research in explaining the variation in TFP and probably the complementarity between the two investments was not ruled out. The study undertook an exhaustive aggregate analysis of various dynamics in Indian agricultural production and productivity. The most interesting point to be extracted from this work was that the returns to public and private sector investments were reasonably very high across all time dimensions including the post-Green revolution period and considerable scope remained to further expand the investment in improving productivity and performance of Agriculture. This study seems to be suffering from more or less the same limitations of the earlier work (Rosegrant and Evenson, 1992) except the fact that study has expanded by incorporating more crops and larger number of variables as sources of TFP.

Desai and Namboodiri (1997) undertook an analysis of the TFP change in the Indian agriculture by analyzing the price and non-price factors affecting productivity for the period 1966-67 to 1989-90. The disintegration of output growth into input and TFP growth was done for the period 1950-51 up to 1989-90. They used a Tornquist-Theil index for constructing a TFP index and the ratio of output index to input index yielded the TFP index, hence postulating TFP as a residual measure of productivity. The authors used trans-logarithmic production function to estimate the production elasticities to aggregate inputs and construct an input index. Among the various factors determining TFP, Government expenditure in agricultural research and extension explained about 87 percent variation in TFP in the post-green revolution period covered under this study. The marginal rate of return on public investment was estimated to be over 20 percent and pointed out that there is a scope for profitable public sector participation in agro-productivity enhancing activities. It is interesting to note that the study found a negative relationship between Barter Terms of Trade (defined as the ratio of Price received by farmers to Price paid for inputs by farmers) and TFP. This was due to increased consumption expenditure as a result of fall in input prices as the increased real income is not spend on acquiring better know-how and training on farming skills. The study also focused on several other sources of TFP growth in the form of rural road density and the distribution of land holdings, but found them to be considerably less important than Government expenditure on R &D. The study could have used competing forms of production functions and analyzed the differences in the results that occur due to different approximations of the agricultural production process. The analysis could have included certain other variables or different forms of variables such as the variability in rainfall instead of the average rainfall, inclusion of private research expenditure, etc. to better point out the sources of TFP.

Kalirajan and Shand (1997) demonstrated the decomposition of TFP growth into technical efficiency change and technological change. This paper throws a theoretical light on how the shift in the production function

can be viewed by two separate parameters that can originate from technology. Apart from input growth the authors have demonstrated the possible shifts in the production function due to TFP growth. This study is an empirical analysis of the sources of agricultural output growth in India but did not go in detail of the other factors that are possibly responsible for TFP growth.

Kumar and Mittal (2006) measured crop-wise agricultural productivity growth between 1971 and 2000. The authors used Divisia-Tornqvist Index to measure TFP and found that benefits of technological development had not been accrued to all crops and that there was disparity in the use of technology. It was found that Paddy and Wheat performed better than other crops in accruing the productivity gains. The authors also found that several crops such as coarse cereals, pulses, oilseeds, fibres, sugarcane, etc. did not have any technological gains especially over the 1990s. The study noted the necessity to decompose the total output growth not into area and yield component parts but rather into input-driven and TFP-driven components, owing to, probably, the decline in the importance of variation in the area under cultivation and soil quality since the 1960s compared to other inputs and the increased importance of technology in shaping the behaviour of agricultural output growth. Sustainability issues were analyzed by using relative measures of sustainable level of farming and production by studying various issues related to the problem of maintaining old yield level with ever increasing amounts of inputs. They found diminishing returns to scale in Indian agriculture. The important policy suggestions that emerged out of this study were that there remained large potential yields from various crops that could be tapped into by further government investments. The study however did not investigate the observed behaviour of TFP beyond an exploratory analysis. In particular, the sources of TFP were not analyzed empirically and had they further investigated their study, then empirical analysis could have contributed much more to the policy-making process related to enhancement of agro-productivity.

Tripathi (2008) investigated the nature of total factor productivity growth of Indian agriculture and allied sector. TFP was estimated as a ratio of total output index (as measured by Gross Value Added in Agriculture) to total input index (as measured by aggregating inputs) for the period 1969-70 to 2005-06. The author undertook aggregation of inputs by production elasticity approach using a Cobb-Douglas production function with Constant Returns to Scale. Production function approach was used because of unavailability of factor price data for the period under consideration. The entire time period was sub-divided into three parts namely 1969-70 to 1979-80, 1980-81 to 1990-91 and 1991-92 to 2005-06, with changing economic policies being the differentiating factor. The study found that over the entire study period the contribution of TFP was negative at -0.11 percentage and agricultural output had grown to the tune of 2.8 percentage and of this, 2.93 percentage could be attributed to the increase in use of land, labour and capital despite negative TFP growth. The study did not go deeper into the various dimensions of TFP behaviour such as its determinants and the possibility of using more exhaustive frameworks, for example allowing for non-constant returns to scale, which might have better depicted the workings of agricultural production process for the stated period.

Tripathi and Prasad (2009) studied agricultural productivity since 1991-92 up to 2005-06 and focused on a crop-wise study of decomposition of agricultural production growth into variations due to yield effect, area effect and interaction effect (combined effect of yield and area effects). The authors found that yield effect was greater than area effect for all major crops except for wheat, sugarcane and potato and also analyzed instability in Indian agriculture by using the Cuddy Della Valle method. The authors also analyzed contribution of traditional inputs in agricultural production and found increasing returns to scale and the impact of labour on output was most pronounced compared to other inputs. This study focused solely on decomposing total production growth into a traditional schema which had been more suitable for pre-Green revolution period when the contribution of land to output growth was probably more important than other inputs. It is debatable whether this division of output changes into area and yield can throw equally meaningful light on output behaviour when the output variations are driven by other inputs including technology. The study also did not get much deeper into estimating TFP and remained limited to a cursory examination of agricultural production. The determinants of agricultural production that are captured by non-conventional inputs were also not taken into consideration.

Avila and Evenson (2010) have extensively conducted study on TFP analysis covering Asian, African and Latin American countries of which India is also a part. They have analyzed TFP through Growth Accounting method and by constructing appropriate production function from Invention-Innovation Capital Index and Technology-Mastery Index. They found that these two constructed indexes played a critical role in TFP. Although, there is a good amount of dispute on the international comparability of data, they managed to bring uniformity to some extent and have thrown light into the new dimensions of estimating technology-mastery index. This study suffers from a lack of country-specific TFP analysis and the policy implications of the same.

Kannan (2011) estimated TFP for the state of Karnataka for ten major crops by using a crop output growth model for the years 1967-68 to 2007-08 with a Cobb-Douglas production function. The study found that trends in income and employment shares of agriculture for the state were similar

to those observed at the national level. It also noted that owing to the higher level of dependency in the state agro sector for employment, the productivity gains were hindered for the major crops under consideration. The scope of the study was limited to only a single state and a regional analysis could have provided more information about productivity differentials across the Southern region of which the selected state is a part of. The study also overlooked the various possibilities of using other methods of constructing a TFP index which could have accounted for more complexity of the Productivity behaviour at a disaggregated level. An exhaustive empirical analysis of the sources of TFP for the selected state could also have shed richer insights into the possibilities of enhancing productivity in the state.

Dev (2012) analyzed key problems of Indian agriculture by undertaking an exploratory analysis of the various aspects of Indian agriculture and found retarding productivity in Indian agriculture. The author also found that among the key problems for Indian agriculture were the high disparities in State GDPs and a larger proportion of small and marginal farmers among the total number of farmers. The study did not account for a detailed investigation of total factor productivity and its related issues pertaining to Indian agriculture and ignored the possibility of deriving aggregate insights into the behaviour of total factor productivity for the stated period.

Chand, Kumar and Kumar (2012) demonstrated the estimation of TFP by using Tornquist-Divisia index for major crops in India for the period of 1975 to 2005. They had specifically analyzed how investment in agricultural research promoted TFP across crops and it was also brought out that with increase in investment in agricultural research the real agricultural production costs felt with respect to various crops. TFP growth was found to have reduced the cost in turn in the range of 1.0-2.3 percent. The Internal Rate of Return calculated for investment on agricultural research was arrived at 42 percent and this gave good amount of scope for positive investment scenario in the Indian agriculture. The study had suggested higher allocation of resources from state-monitored and funded agencies. This study did not take into account of the key variables that are responsible for productivity growth and was restricted to only aggregate investment measures.

Reddy (2012) had examined the production and other related issues of Orissa (now Odisha) for the period 1991 to 2008 and although this study is not directly relevant to productivity analysis but some aspects of productivity and its related issues were covered. It had been observed that Orissa was not using fertilizers, HYV and good amount of technological inputs as compared to other states and the author noted that probably the use of all such factors would produce enhanced TFP which might reduce regional disparities across various regions and districts in Odisha. Estimated technical inefficiencies gave insights into the various dynamics that are involved in productivity related issues. Income gain can be possible if diversification of crops and use of HYV can be accompanied with technological know-how.

Lack of convincing and conclusive results, differing methodologies used over a wide spectrum of studies and lack of exhaustive and conclusive productivity analysis for the post-reform period among others, motivated the literature review undertaken by the present study.

Exploratory note on key issues related to total factor productivity: The studies on TFP in the Indian context are neither exhaustive nor limited but there is considerable scope for more detailed investigations into the various dimensions of productivity measurement and policy analysis. Some comprehensive issues which are critical to understand the TFP measurement and growth can be brought through an exploratory analysis of the evidences available in the public domain for understanding some of the issues which are critical for research.

First, the main analytical and operational area of research pertaining to the TFP is the methodological foundation. As mentioned earlier, the approaches with which TFP measurement has been operationalized can broadly be classified into the Index number method, Growth accounting method and Econometric method. Most of the studies have based their analysis on Growth accounting method followed by Index number method. Although, each methodology has its own limitation, the Growth accounting method remains quite popular in the context of Indian agricultural research. The use of this particular method is popular in India primarily due to conceptual operationalization of available information for estimation and the adaptability for computation.

Second, within the Growth Accounting framework, a new data environment for productivity analysis has recently emerged in the form of the database of the India-KLEMS research project that aims to address several critical issues pertaining to the available and popularly utilized empirical information on TFP estimation in the context of Indian agriculture. These issues include but are not limited to developing clearer and more specific aggregate and industry-wise measures of labour and capital, the construction of continuous time series on shares of various industries in aggregate value-added and aggregate gross output, constructing reliable aggregate and industry-level estimates of intermediate service inputs, splitting of available aggregate data into disaggregated information on key variables related to TFP estimation, estimating the aggregate and industry-specific quantities of labour input in a manner that takes into account the changes in labour quality and composition, generating continuous time series on both industry-specific and economy-wide estimates of capital stock and capital

services, construction of gross output estimates as well as gross value added measures of aggregate production, estimation of internationally comparable and National Accounts Statistics (NAS) compatible TFP time series, and other related matters. Some studies have been undertaken using data supplied by the KLEMS data base though the analytical framework utilized has largely been within the Growth Accounting tradition.7 It was however found that there were no studies that explicitly examined TFP behaviour specifically for the Indian agricultural sector and the sources and determinants of agro-TFP in India using the KLEMS framework.

Third, the problem of input aggregation has been a noteworthy constraint on the kind of methodology employed by the researcher. The aggregation of heterogeneous inputs into a single index number requires some weighting methodology which can help combine these entities. The weighting factors8 used can be classified into cost weights, factor-price, factor-income weights, and in absence of data on these variables, production elasticity weights. The last one can also be considered as output-share weights as the output elasticity of each factor of production such as land, labour and capital, is used for adding the inputs into a common index. The aggregate level analysis especially for more recent periods inevitably faces the constraint of lack of continuous time series on factor prices and factor cost data and hence the use of production elasticity approach has been popular among researchers. The more disaggregated analyses of productivity behaviour that focus on specific crops have been able to construct relevant indexes such as Tornquist-Theil index, using shares in total cost and/or factor prices of individual crops to aggregate the conventional inputs. It should however be noted that the KLEMS database do provide continuous time series on factor income shares for labour and capital inputs for various sectors including the agricultural sector. However, currently these data are available only for the period 1980-81 up to 2011-12.

Fourth, within the Growth accounting framework lie the two major approaches to decomposition of agricultural output growth for understanding the contribution of conventional inputs and identifying total factor productivity. These methods are broadly classified as the area and yield growth method and the input and TFP growth method (Kumar and Mittal 2006). The area-yield approach was particularly popular in the pre-Green revolution period when the land-input played a much more dominant role in agricultural output growth. However, with the advent of Green revolution, the introduction of new technologies and scientific know-how into the agricultural production process has resulted in dominance of technology and other non-conventional factors as key sources of agro-output growth. Owing to all these changes and also application of HYV and the diversity in cropping-pattern, the decomposition of output is analyzed through input-TFP method. Although the success of Green revolution including the recent attempts to revive the Green revolution in the name of Second Green revolution at different levels have more or less remained partially successful and restricted to few regions and pockets. The available evidences suggest that the significance of technologically driven Total Factor Productivity has on an average been stagnant across different regions at aggregate level, though it may not be purely true at the disaggregated level for various crops. The basic inputs such as capital and labour have been playing an important role in determining the changes in agricultural output.

Fifth, detailed availability of time series data on various aggregated variables consisting of capital and labour has been a matter of concern and most of the studies have either modified or applied some statistical technique to generate continuous time series data. This might endanger the very basic relationship on Data Generating Process. The constraints that they impose on extrapolation and interpolation and also on using any other statistical method could very well either underestimate or overestimate the parameters. Looking into the various studies it is increasingly difficult to conclusively say that the reliable method is brought for obtaining continuous and authentic data on time series in the Indian context.

Sixth, the measurement and estimation of TFP in agriculture and its impact on agricultural output growth essentially depends on the sample and time period chosen for the analysis. Depending upon different samples, the analysis varies in terms of the factors that determine TFP and good amount of variation across various studies and, in fact conflicting evidences are observed. In particular, the fundamental shifts in the estimates and sources of TFP have been observed between the pre-reforms and post-reforms periods. Considerable amount of increase in investment and privatization has not taken place in agriculture. Co-operative farming, Community and Rural joint management concepts are not developed to enhance the productivity.

Seventh, although there are some studies which focused on the micro-level analysis, most of the studies are conducted on macro-level issues and data. It is very difficult to have holistic perspective on a heterogeneous and complex topic which varies across regions and crops without having proper regional, district and micro-level studies. Empirical evidences in the Indian context have not articulated such cross-section of issues pertaining to TFP that are essentially important for Government policy-making on food security, retention pricing, minimum support price, fertilizer subsidy, etc. Had there been the presence of various micro-level and region-specific studies, the policy making could have been much clearer and unambiguous. It is important to mention that the quantum of private investment has been consistently higher than public sector investment in agriculture at

aggregate level and, even if investment is pushed in some pockets, there is a good amount of variation in the levels of investment across the various regions thereby not making it uniform for productivity spread.

Lastly, there are a variety of methods in the available evidences on TFP estimation and this might point to the fact that there exists no single measure of TFP that can claim to be the best method among all competing estimates that can probably reflect the underlying data generating process. If long term information is available, then it is important to estimate TFP rather than partial factor productivity for understanding the behaviour of fluctuations in the agricultural output. It is also imperative to mention that still in India the agricultural sector provides maximum employment opportunities and the phenomenon of disguised unemployment is not clearly resolved. The impact of disguised unemployment on productivity has not been properly investigated in the available evidences. Owing to this fact, the productivity measurement becomes very difficult when we decompose in terms of various factors including labour.

CONCLUSION

This attempt throws some important insights and discusses several critical issues involved in TFP measurement and estimation by bringing forth the debates around major studies. One can fully understand that the studies reviewed here are only considered on account of their representativeness of the underlying patterns and trends in productivity research in India. It goes without saying that it is not an exhaustive analysis on review but gives an account of analysis on critical landmark works that are carried out for various themes on TFP. It can be noticed throughout our discussion on review of literature that there are a good number of thought-provoking issues associated with TFP but evidences are conflicting, sometimes controversial and subjected to further detailed investigation. Still, there is a good amount of scope for future research on the measurement, estimation and analysis of the determinants of TFP. This might include expanding areas of sources of TFP growth, allowing it for incorporating more information on time series, including survey-based cross section studies for regional analysis, eliminating the limitations of methodological issues encountered by the existing studies, taking into account the policy shifts in agriculture vis-a-vis productivity, developing a complementary approach across aggregated and disaggregated studies for unifying factually possible information for the better understanding of TFP, and, taking into account sustainable growth, ecology and environmental issues. We hope that the world of literature on TFP might receive good number of further studies that might possibly address these concerns.

NOTES

1. For more extensive work on theoretical foundation refer to neoclassical theory by J. E. Meade and others.
2. Considerable amount of debate exists on whether and under what economic conditions and assumptions TFP represents only technical efficiency rather than technological progress as well as technical efficiency both. For a brief overview on this issue, see Kalirajan, Obwana and Zhao (1996).
3. In case of Agriculture sector, the concept of TFP might require further decomposition to extract information about the technical change component as against changes in output due to weather conditions and capacity utilization (Dholakia and Dholakia 1993).
4. It is important to understand that this classification of the methodological frameworks into various types can only provide an analytical ease of understanding the various issues faced by researchers when measuring TFP. The classification made here broadly divides the various approaches to TFP measurement but also recognizes the possibility of inter-relations in the applications of these methods. Studies on TFP can make use of some aspects of these three techniques together but at the same time they might analyze TFP within the single given framework. For example, the Growth accounting approach to measurement of TFP might presuppose the use of Index Numbers but only to the extent that heterogeneous inputs or heterogeneous outputs in case of disaggregated analysis which have to be aggregated into a single variable. Beyond this, it is possible to use Growth Accounting method while not utilizing the varieties of indexes available for estimating TFP such as Tornquist-Theil index or the Divisia index even though their use shall also help extract nearly similar information, though via different analytical routes. In the same way it is also possible to use an Index number approach without having to explicitly adopt the growth accounting framework as in the case of estimating different indexes as mentioned above. Finally, while utilizing the index number approach or even the growth accounting approach, the estimation of production elasticities might make it necessary to use some econometric methods. See Kumar and Mittal (2006) and Kannan (2011) for further related discussions.
5. The Growth accounting method works under a neoclassical framework and several important debates and controversies have characterized this tradition. For example, the famous Cambridge Capital Controversy has had important implications for the developments in the neoclassical aggregate production function analysis. The neat classification of Capital into a single input for aggregate productivity analysis invited several criticisms and various important dimensions have emerged from these debates. For more details, refer to Rymes, T. K. (1972).
6. Good amount of literature is already available on the detailed analysis of various methods of measurement of TFP,

and therefore, this study does not attempt to reproduce detailed account of the various techniques. For a brief overview on the mechanics of the methods discussed here, see Saikia (2014).

7. More detailed analysis on the various conceptual issues and empirical application of the KLEMS database in the context of TFP estimation for Indian economy as well as some aspects related to TFP analysis for the Indian agricultural sector can be found in Krishna, Erumban, Das, Aggarwal & Das (2017) and Das, Erumban, Aggarwal, Das (2015) among others. More information on these matters with reference to the United States can be found in Strassner, Medeiros & Smith (2005). A detailed discussion on key issues in this context and with special reference to the TFP estimation for the European Union can be found in O'Mahony & Timmer (2009). The Indian database is a part of the India-KLEMS research project and by and large follows the EU-KLEMS. Other such databases include, Asia-KLEMS and the World-KLEMS that are available for public consumption and can be utilized for international comparisons due to the fact that all these databases have been constructed using similar methodology and measurements. More economies are being covered under this research project and the available data is continuously updated with the latest one as of writing this paper being that of the year 2016 in the Indian context. It is still a matter of further research to examine the country-specific differences in definitions, measurements and scope of the variables that might have emerged on account of the fact that the data collection process, timing and the data collecting agencies differ across these regions.

8. For more detailed analysis of problems in combining heterogeneous inputs into a single variable and various other connected issues, see Daly (1972) and Creamer (1972).

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