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WBSTFP: Software for TFP Computation in Agriculture

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SUMMARY

Productivity growth in agriculture is both necessary and sufficient condition for its development. Total Factor Productivity (TFP) is that part of growth in output, which cannot be explained by growth in factor inputs like land, labour and capital. The purpose of this paper is to describe process model, features and functional details of a web based software for computation of total factor productivity (WBSTFP). Software is based on standard three tiers of web architecture. Development is carried out using .NET technology. Software is completely menu driven and user-friendly. Being online system, web browser is the only requirement at user end. The software provides output in the form of TFP index, output index, input index, growth and growth curve of each index. This software is useful for economists, statisticians and other agricultural researchers working in the area of agricultural productivity.

Keywords: Agricultural productivity, TFP, Web based software, WBSTFP.

1. INTRODUCTION

Agricultural productivity is defined as the ratio of agricultural outputs to agricultural inputs. While individual products are usually measured by weight, their varying densities make measuring overall agricultural output difficult. Therefore, output is usually measured as the market value of final output. This output value may be compared to many different types of inputs such as labour and land (yield). These are called partial measures of productivity. Agricultural productivity may also be measured by what is termed total factor productivity (TFP). TFP is an important measure to evaluate the performance of any production system and sustainability of a growth process (Kumar *et al*. 1992). Total Factor Productivity (TFP) is that part of growth in output, which cannot be explained by growth in factor inputs like land, labour and capital. Total factor productivity index (TFPI) compares an index of agricultural inputs to an index of agricultural outputs. TFPI was established to remedy the shortcomings of the partial measures of productivity which fails to identify the factors that cause them to change.

There are mainly two types of methods to estimate TFP (Coelli *et al*. 2002). The methods involving econometric estimation of production models are called parametric methods. The methods which do not involve econometric estimation are called non-parametric methods. The present paper discusses the process of development of web based software using a non-parametric formula for estimation of TFP. The study does not aim to improve various mathematical formulae available in literature but is based on Tornqvist index which is a most popular and preferred method for

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estimation of TFP (Coelli *et al*. 2002). Tornqvist index exist in three forms namely Tornqvist quantity index, Tornqvist price index and Tornqvist productivity index. Tornqvist productivity index has been widely used for the studies involving productivities changes. Tornqvist productivity index is the ratio of aggregate output index (a kind of quantity index involving one or more than one outputs) and aggregate input index (also a kind of quantity index involving one or more than one inputs). TFPI is useful for comparisons across time periods or production units. Economic theory issues dealing with comparisons are outside the scope of this paper and can be referred in literature (Coelli *et al*. 2002). However, based on the discussion on index numbers and productivity indices in Chapter 4 and Chapter 5 by the authors (Coelli *et al*. 2002), mathematical foundations for TFP computation using Tornqvist index is briefly presented in following sub-section.

1.1 Mathematical Foundation

Computational methodology, used in this paper for TFP estimation, is based on Tornqvist index. For the purpose of simplicity in understanding, we start with the case where only one output is produced using one input. Next, we discuss the mathematical formula for a practical case where many inputs are used to produce many outputs.

1.1.1 Case I: One Output and One Input

Let us first consider a case of single output in a production unit (such a case is rare because by-products are also valued in many enterprises). Total output index for a time period t (TOI_t) is a ratio of output quantity produced during the period t (Q_t) and the consecutive previous period (Q_{t-1}). Mathematically, it can be expressed as

$$TOI_t = \frac{Q_t}{Q_{t-1}} \tag{1}$$

where the subscript t represents a year or a time period t and the subscript t-1 represents a consecutive time period prior to t.

Similarly, total input index (TII) can be computed for situations where only one input of quantity X is used. Total input index for a time period t (TII_t) can be expressed as

$$TII_t = \frac{X_t}{X_{t-1}} \tag{2}$$

where X_t is the quantity of the single input used for production during time period t and X_{t-1} is the quantity of the input used during the consecutive previous time period t-1.

Total factor of productivity index (TFPI) during a period t is a simple ratio of total output index and total input index. Mathematically,

$$TFPI_t = \frac{TOI_t}{TII_t} \tag{3}$$

where the numerator and denominator are obtained from equation 1 and equation 2 respectively.

1.1.2 Case II: Many Outputs and Many Inputs

(a) Total Output Index

Let us consider the case of m outputs. Further, let each output is identified by the subscript j where j varies from 1 to m. For example, Q_{jt} denotes the quantity of output j during a time period t. For computation of total output index, one requires the value of each output (so as to estimate corresponding weight) as it is improper to add quantities of different products having different densities and values. For example in agriculture for a wheat crop two outputs are grains and fodder. Here, we cannot simply aggregate the quantities of grains and fodder to get the quantity estimate of total output. Instead, we need to take into account value (product of quantity and price) of each output to aggregate all output quantities. For such cases, the Tornqvist index, defined as a weighted geometric average of relative quantities with weights given by the simple average of the value share in time periods, is useful to aggregate outputs. Mathematically, it is represented as

$$\textit{Total output index} = TOI_t = \prod_{j=1}^{m} \left(\frac{Q_{jt}}{Q_{jt-1}} \right)^{\frac{1}{2}(R_{jt}+R_{jt-1})} \tag{4}$$

where Q_{jt} is the quantity of the output j produced during time period t, Q_{jt-1} is quantity of output j during time period t-1, R_{jt} is value share of output j in total revenue of all outputs during time period t, and R_{jt-1} is value share of output j in total revenue from all outputs during time period t-1.

It should be noted that the subscript $(R_{jt} + R_{jt-1})/2$ represents the average value share of output j for time period t and time period t-1. The value share of output j (R_{jt}) in the total revenue collected from all m outputs of the enterprise is computed using the formula

$$R_{jt} = \frac{V_{jt}}{\sum_{j=1}^{m} V_{jt}} \tag{5}$$

where V_{jt} is the total price value of the output j and the denominator represents the total revenue of the enterprise under consideration. V_{jt} can be computed by multiplying the total quantity of the output j (Q_{jt}) with the respective price per unit quantity (P_{jt}). Mathematically, V_{jt} is

$$V_{jt} = Q_{jt} \times P_{jt} \tag{6}$$

(b) Total Input Index

Let us assume that there are n inputs and each one is denoted by the subscript i where i varies from 1 to n. Let X_{it} denote the quantity of input i during time period t. Now to compute total input index one requires the cost value of each input as it is improper to directly add quantities of different inputs like fertilizer, labour, pesticides, seeds etc. where each one has different density or different unit or different cost value. We need to take into account cost value (product of quantity and unit cost price) of each input to aggregate all inputs. Similar to total output index, Tornqvist quantity index can be used to compute total input index (TII_t). Mathematically, it is represented as

$$\text{Total input index} = TII_t = \prod_{i=1}^{n} \left(\frac{X_{it}}{X_{it-1}} \right)^{\frac{1}{2}(S_{it} + S_{it-1})} \tag{7}$$

where n is number of inputs,

X_{it} is the quantity of input I during time period t,

X_{it-1} is the quantity of input i during time period previous to t,

S_{it} is the share of value of the input i in total value of the inputs during time period t, and S_{it-1} is the share of value of the input i in total value of the inputs during time period t – 1.

In equation (7), value share of each input during a time period t (S_{it}) is computed using the formula

$$S_{it} = \frac{C_{it}}{\sum_{i=1}^{n} C_{it}} \tag{8}$$

where C_{it} is the total cost value of input i. Total cost of an input is calculated as product of quantity of that input and respective unit cost price of the input. Mathematically,

$$C_{it} = X_{it} \times P_{it} \tag{9}$$

where P_{it} is the cost price of input i during time period t.

(c) Total Factor Productivity Index

Analogous to total output index and total input index, total factor productivity index (TFPI) for a time period t is denoted by $TFPI_t$. It is defined as the ratio of TOI_t and TII_t and measures the technological change with reference to the previous consecutive period t-1. For better estimation, the period t should be small viz. annual period in case of agriculture enterprises where production is accounted annually and the corresponding data is published. Thus

$$TFPI_t = \frac{TOI_t}{TII_t} \tag{10}$$

where the TOI_t and TII_t are computed from equation 4 and equation 7.

(d) Total Factor Productivity Index for Longer Time Periods

In empirical analysis, we are often required to compute TFP changes for bigger time periods like a decade. Literature mentions that for such cases of productivity measurement over a long period of time (say 10 years or 20 years or even more), we are also interested in comparing each year with a previous year, and then combining annual changes in productivity to measure changes over a given longer period. The index constructed using this procedure is known as chain-base index or chain index and is denoted by asterisk as a superscript.

To facilitate a formal definition, let $I(t\text{-}1, t)$ define any index of interest for period t with t-1 as the base period. The index can be applied to a time series with t = 1, 2.., T. Then a comparison between period t and a fixed base time period 0, can be made using the following chained index of comparisons for consecutive periods.

$$I(0, t) = I(0,1) \times I(1, 2) \times I(2, 3) \,..\, I(t-1, t) \quad (11)$$

As an alternative to chain index, it is possible to compare base time period 0 with period t using the equations described earlier and the resulting index is known as fixed-base index. However, the discussion is beyond the scope of the present paper. From a practical angle for measurement of productivity changes, since the chain index involves only comparisons with consecutive periods, the index is measuring smaller changes. Therefore, some of the approximations involved in the derivation of theoretically meaningful indices are more likely to hold (Coelli *et al*. 2002, page 81). More details on chain index and its comparison with fixed base index can be referred in literature (Ahn and Abt 2013).

Following the recommendations provided in productivity measurement literature, WBSTFP has been developed using the chain-base index method for computing TFPI because of its relative merits over fixed-base index. Adoption of chain index equation for TFPI estimation is depicted in following paragraphs.

Let the notation TOI_t^* represents $TOI(0, t)$ *i.e*. total output index of year t with 0 as the base year and TOI_t represents (as discussed above) total output index of year t relative to the year t-1. Similarly TII_t^* denotes total input index of year t relative to base year (say 0) and $TFPI_t^*$ refers to total factor productivity index of year t relative to base year 0. Adoption of equation (11) for computing TOI_t*, TII_t* and $TFPI_t$*, we derive the following equations.

$$TOI_t^* = TOI_1 \times TOI_2 \times \ldots \times \ldots \times \ldots TOI_{t-1} \quad (12)$$

$$TII_t^* = TII_1 \times TII_2 \times \ldots \times \ldots \times \ldots TII_{t-1} \quad (13)$$

$$TFPI_t^* = \frac{TOI_t^*}{TII_t^*} \quad (14)$$

In equation (12), it should be noted that TOI_t^* (a chain type index also called the total output index for the period t with reference to the implicit base time period 0) has been computed by multiplying all TOIs of the previous years starting from year 1 to year t-1. Thus TOI_t refers to an annual total output index for the year t with reference to the immediately preceding year (say t-1) while TOI_t^* is for a period t with reference to base year (say 0 denoted by asterisk as a superscript). Similar concept has been used for notations TII_t^* and $TFPI_t^*$.

1.2 Existing System

Most of the agricultural researchers use spread sheets and repeated calculations for computation of TFP. Spread sheets are able to manage computation if there is only one crop and computation of TFP is required for a single specific spatial unit (say country) for which data is already in aggregated form. However, management of computation using spread sheets becomes increasingly difficult when more crops and more locations are to be considered. For example, for computing TFP of cereal crops, horticulture sector etc. there is a need of considering many crops together. TFP computing becomes more complex and also highly vulnerable to human errors if data is available for lower level spatial units (say districts) and TFP estimation is required for a higher level spatial unit like state or the country. Realizing the problems, an attempt was made by Tim Coelli to automate the process of TFP computation (Coelli *et al*. 2002). A computer program called TFPIP (Total Factor Productivity Index Program) was developed for the purpose of computing index numbers for input and output quantities, as well as resulting TFP index (http://www.uq.edu.au/economics/cepa/tfpip.htm). The system reduced the drudgery of computation of TFP when aggregation of spatial units is not required. While using TFPIP, one has to do aggregation manually for a higher spatial unit (state, country or a region) from the compiled data of lower spatial units (district or state). This step is computationally intensive and prone to calculations' errors. Further, more computational intensive step is dealing of multiple crop output and many spatial units simultaneously while computing TFP for a place. Besides, the software TFPIP is not compatible to the spread sheet format which is generally used by researchers for data preparation. System also has another major limitation, as reported by Tim Coelli himself, that program is written for DOS environment and is not compatible under Windows environment.

1.3 Proposed System

Based on study of the existing system, it is identified that there is a need for software which can support spread sheet based input data files and also facilitate direct computation of TFP for higher spatial units from the data collected for lower spatial units. The main contribution of the proposed system is that it automates the process of aggregation of inputs from crops to the sector (*e.g*. agriculture sector, horticulture sector) or from districts or states to country level. The weighted aggregation is based on the value share of the crop or lower spatial unit in the sector under consideration for the selected higher spatial unit. The proposed system is compatible with latest operating systems and internet technologies. The system provides many important features like (i) online availability, (ii) dealing with multiple places and multiple crops at a time, (iii) place wise and crop wise aggregation, (iv) help module, (v) computation of growth of indices, (vi) graphical representation of growth curve and (vii) flexibility in data handling. The software has been designed and developed taking advantage of the .NET framework. The software is referred as "Web based software for computation of Total Factor Productivity" (WBSTFP).

1.4 Stakeholders

Computation of TFP is mainly dealt by researchers, agricultural economists, policy analysts, students and academicians. WBSTFP is online software that can be accessed using the default browser of the user system. The stakeholders are not required to have any exposure for installation of the software, writing scripts and programming as WBSTFP is user friendly. WBSTFP users are released from the burden of downloading, installing, dealing with the issues of incompatibility of hardware and writing scripts or macros. This paper makes an attempt to explain the process model, functionality and unique features of the software and develops interest and insight for computing TFP using the software.

The paper is organized in five sections. Section 2 provides details on TFP process model, development methodology, architecture and design. Section 3 deals with functionality and unique features available in the proposed method. Section 4 presents results and discussion followed by conclusion in Section 5 and references at the end.

2. TFP PROCESS MODEL

Software process model is a framework that describes the activities to be performed at each stage of a software development project. Many software development process models are available in literature (Jalote 2009, Sommerville 2009). A process model for the software is chosen based on the nature of project and application. WBSTFP system was developed using Waterfall model. Requirement analysis and design are the two initial steps which need to be addressed as they are building blocks for any software.

2.1 Requirement Analysis for WBSTFP

Requirements are set of functionalities and constraints that end-user (who will be using the system) expects from the system. Information about user's requirements has been gathered by consulting agricultural researchers working in the domain of productivity analysis and also from the literature (Chand *et al*. 2011). Functional and non-functional requirements are two major types of requirements that are gathered under requirement analysis phase. Functional requirements included automating computation of output index, input index and TFP index based on equations discussed in Section 1. The data should be uploaded by user in Excel sheet. Users also required flexibility for entering data pertaining to smaller spatial units (say districts) for computing TFP for a higher spatial unit (say state) for a single crop or for multiple crops of a sector like cereal crops, oilseed crop etc. This extra facility was desired besides existing method in which data should be fed to the system for the spatial unit for which TFP is computed. For displaying the results, users wanted all indices, growth rate of each index and the corresponding growth curve. Further, the results should be exportable in EXCEL format to facilitate further research analysis.

Among non-functional requirements user friendliness, maintenance free for stakeholders, reliability, accuracy and compatibility with the existing browsers and operating systems were the obvious requirements.

2.2 Architecture and Design of WBSTFP

Software design is a multistep process which focuses on four distinct attributes of a program; it includes data structure, software architecture, interface representation and procedural details. WBSTFP is designed as a web based application, which can be accessed for updating and reviewing from any node on the Internet through a web-browser.

Standard three-tier client server architecture is used for the development of this web application which includes User Interface layer, Application layer and Database layer. User interacts with software through User Interface Layer. This layer is developed using Hyper Text Mark-up Language (HTML), Cascading Styling Sheet (CSS) and JavaScript. Business logic has been implemented in application layer using HTML, Java Script, ASP.NET programming framework along with C# (Chris *et al*. 2006; Bayross 2000; Frentzen 1999). Web server, Internet Information Server (IIS) is used for hosting the application. ActiveX Data Object (ADO) is used for creating connectivity to database and server side objects (Chris *et al*. 2006). Database transactions are done using Structured Query Language (SQL) (Vieira 2006). Database Layer (DBL) layer is developed using Microsoft Access (MS-Access). Database contains two independent tables namely login table and price table. Login table facilitates tracking of users of the system and price table stores price index which is required during computation of TFP for the uploaded Excel sheet.

2.2.1 System Design

System design and flow of information is further represented using Data Flow Diagram (DFD). DFD (also known as bubble chart) is a simple graphical formalism that is used to represent a system in terms of the input data in the system, various processes carried on these data and output data generated by the system (Jalote 2009). DFD for TFP computation shows that data is inputted by user in Excel file having three sheets namely agricultural production data (APD), agricultural input data (AID) and price index (Fig. 1).

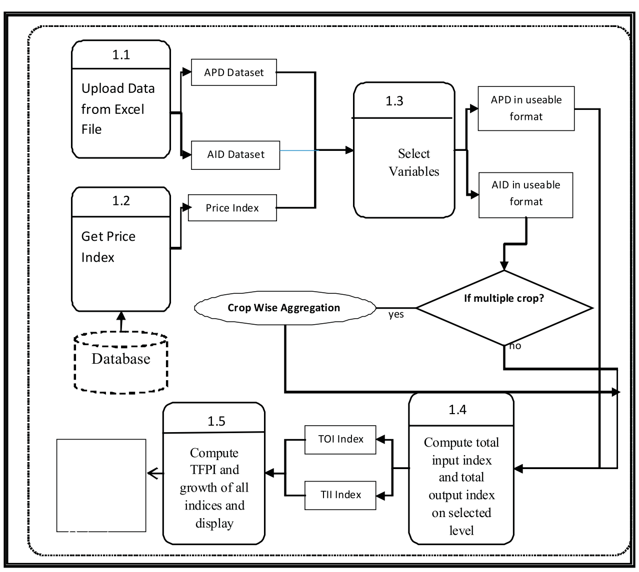


Fig.1. Data flow diagram for WBSTFP

The Excel file is uploaded through process 1.1 and creates APD dataset and AID dataset. The price index data set could be acquired either from database or from Excel sheet of price index by using process 1.2. After acquiring these three data sets, APD and AID data sets are converted into useable formats through process 1.3. After aggregation (if required), two data sets (APD and AID) are passed onto process 1.4 as input. Computation of total output index (TOI) and total input index (TII) on a selected level is done by process 1.4. After, getting TOI and TII as input, process 1.5 computes TFP index (TFPI), computes growth of all indices and displays indices and growth parameters.

2.2.2 Designing Modules and Use Case Diagrams

WBSTFP has been designed into different modules taking into consideration the requirements of stakeholders and administrator. Modular design for WBSTFP is presented in Table 1.

Table 1. Modules for TFP computation

Module Name	Description
Login	Provides facility of login to users and administrator
TFP computation	The main module, which provides TFP index (including output index and input index), growth, TFP growth curve for single and aggregate crop
Help	Provides online help about software
Contact Us	Contact details of developer team
Sample Data Download	Downloads sample data to understand format of input data
Admin Page	Administrator facility to change users information
Signup	Provide facility of sign up to new user
Changed Password	An option for change of password
Password Recovery	Provide facility to recover password

Access rights to different modules for the two categories of users are represented with the help of use case diagram in Fig. 2, Fig. 3, Fig. 4 and Fig. 5. A use case is a description of a potential series of interactions between a software module and the user (Jalote 2009). In use case diagram (Fig. 2), a rectangular box represents user and an oval shape represents use case. Fig. 3 shows system design of login module. Admin page module can be accessed only by the software administrator who is authorized for user management (Fig. 4). TFP computation module (Fig. 5) is further divided into two sub modules. Two sub modules can accessed by both type of users. Both modules (single crop or aggregate crop) for TFP computation would accept data in Excel format and execute the process of TFP computation.

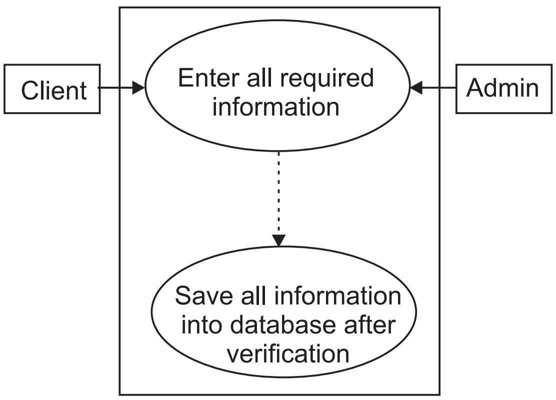


Fig. 2. User case diagram

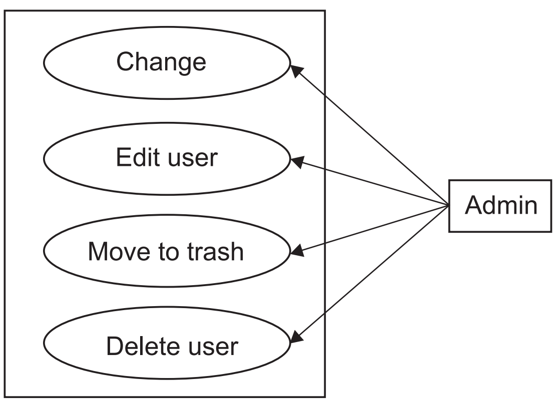


Fig. 3. Login case diagram

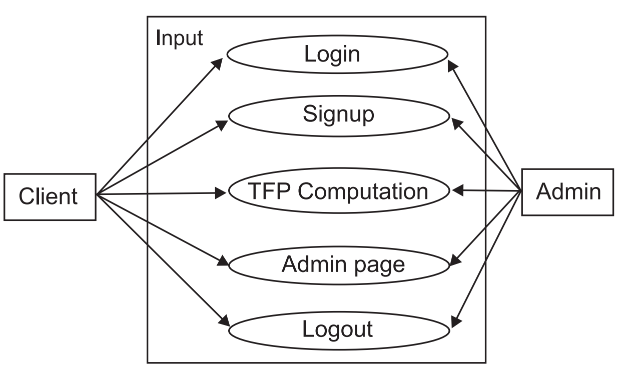


Fig. 4. TFP computation case diagram

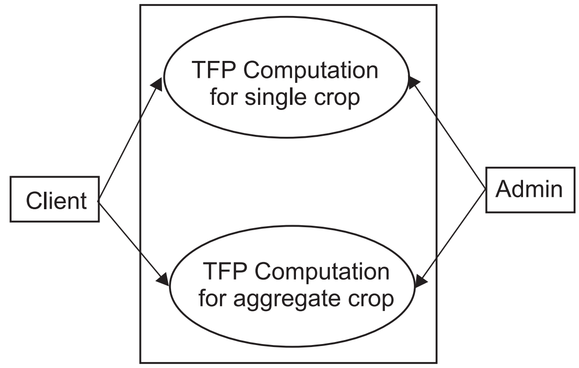


Fig. 5. TFP computation case diagram

2.2.3 Input-Output Design

The application for TFP computation requires input data in Excel format. As presented in DFD, Excel sheet should have three sheets. APD sheet contains annual agricultural production data for single crop or multiple crops. Similarly AID sheet contains annual agricultural input data for each crop and sheet for price index contains data about price index for different years.

Table 2. Design of input sheets for single crop

ID	Full Name	Data Sheet Columns	Description
APD	Agricultural Production Data	Location, year, production of main product (say p_1), value of main product (say v_1), By-product value (say bv_2)	More than one product is allowed in data sheet
AID	Agricultural Input Data	Place, year, agricultural input quantities ($x_1...x_n$), cost of inputs ($c_1...c_a$), cost of all inputs ($cp_1..cp_{n-a}$) where no quantities available	More than one inputs are allowed in data sheet
PIS	Price Index Sheet	Place name, year, index	Place name refers to the location for which price index is given

The designs for three excel sheets for single crop and single level are presented in Table 2. Let us assume that *n* numbers of inputs are required to produce a single crop in a single spatial level. Out of all inputs (say *n*), there are some (say *a*) inputs for which quantity as well as total cost of input is available. For the rest of inputs (*n*-*a*) only cost is available. This is the case when it is not feasible to collect quantity data for some inputs like irrigation, machine use etc. Then column 3 and 4 in AID sheet is repeated a times and column 5 is repeated (*n*-*a*) times.

Variations in component of datasheets are allowed based on number of spatial levels and number of crops. The variations are organized in Table 3 and Table 4.

Outputs for WBSTFP are computed values of TFP index and growth curve of all indices. TFP index are displayed in tabular format containing one column each for TOI, TII and TFPI. Output can be obtained in graphical format also in the form of growth curve. Growth curve is a two dimensional line chart where *X* axis represents timeline (year) and *Y* axis represents index value. Growth curves are optional for TOI, TII and TFPI.

Table 3. Variation in sheet design

Variation	**Action**
Multiple spatial level (say *n*)	Column 1 *i.e.* location will repeat *n* times if there are *n* spatial levels.
Multiple crops	❖ Column 3 and 4 (p_i,v_i)will repeat *c* times for each crop's main product; if *a* crop produce *bp* number of by-products then column *bv* will repeat *bp* times to represent each by-product. ❖ Let us assume that n_i numbers of inputs are required to produce i^{th} crop in a particular level. Out of n_i inputs, there are a_i numbers of inputs for which quantity as well as total cost of input is available. For the rest of inputs (n_i-a_i), only cost is available. Then xi, ci will repeat a_i times and column cpi will repeat n_i-a_i times (where i = 1 to *c*).

Table 4. Differences in design of Excel sheets for single and aggregated crops

Single Crop	Aggregated Crops
Output sheet contains data for single crop.	Output sheet contains data for multiple crops.
Input sheet contains data about input required to produce that crop.	Input sheet contains data about input required to produce each crop.
No condition applies to sheet.	specify header name in any Header name in Input Sheet use dot (.), to separate crop name and input type.
No crop wise aggregation is required.	Crop wise aggregation is done automatically.

2.2.4 Algorithmic Design

Once the data for TFP computation is uploaded and variables and spatial level selection is completed, the request goes to the server and server side calculations are done. The computed results are sent to the clients and results are displayed on the client screen. The methodology used for TFP computation is well explained in Section 1 and also in literature (Chatterjee 2005, Dholakia and Dholakia 1993, Kumar *et al*. 2004, Rosegrant and Pingali 1994). Algorithmic steps that are required to convert alternative forms of inputs into desired output are

1. If TFP is required for single crop, then there could be following two types of computational requirements.
   (a) Compute TFP and (including output index and input index) of any lower spatial level (say for a district) for that crop.
   (b) Compute TFP (including output index and input index) of higher spatial level based on lower spatial level data for that crop.
2. If TFP is required for multiple crops for a sector, then there could be following two types of computational requirements.
   (a) Compute aggregated TFP (including output index and input index) for that sector of any lower spatial level (say for a district).

(b) Compute aggregated TFP (including output index and input index) for that sector of higher spatial level based on lower spatial level data.

3. Compute growth of all indices for all location.

4. Compute and plot graph.

2.2.5 Integration and System Testing

Testing focuses on the logical internals of the software, ensuring that all the logic is working correctly. Testing for each module should be done manually using prototype data. After development and testing of each module, bottom up integration method is applied. In this method all the modules are added or combined from lower level hierarchy to higher level hierarchy. Test cases in Excel sheet were designed for testing of TFP indices computed by the proposed integrated software.

3. FUNCTIONALITY OF WBSTFP

WBSTFP is web based software which can be made accessible to administrators as well as clients through internet. Home page of the software, estimated TFP and corresponding growth curve for the sample data is presented in Fig. 6, Fig. 7 and Fig. 8 respectively. User has to be registered member of the system for using this software.

TFP estimation facility is provided for single crop as well as aggregated crops. TFP estimation being the heart of the software is explained below for single crop as well as for aggregation of crops.

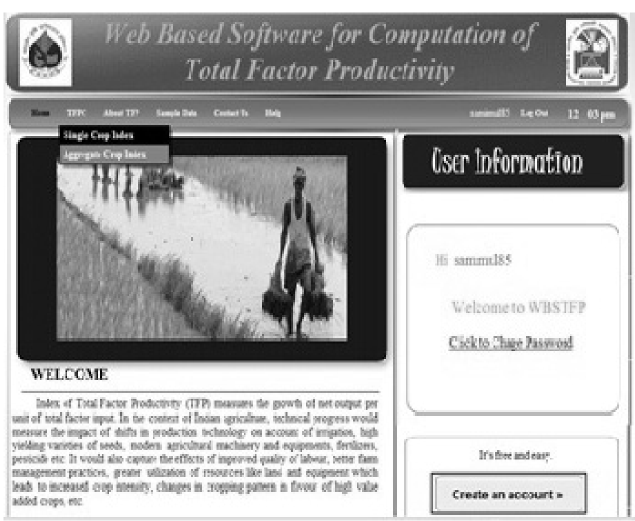
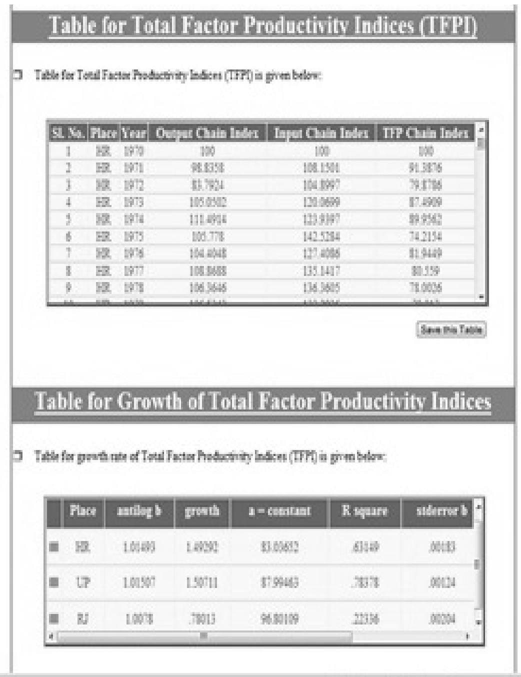


Fig. 6. Home page



Sl. No.	Place	Year	Output Chain Index	Input Chain Index	TFP Chain Index
1	HR	1970	100	100	100
2	HR	1971	98.8358	108.1501	91.3876
3	HR	1972	83.7924	104.8997	79.8786
4	HR	1973	105.0502	120.0699	87.4909
5	HR	1974	111.4914	123.9397	89.9562
6	HR	1975	105.778	142.5284	74.2154
7	HR	1976	104.4048	127.4086	81.9449
8	HR	1977	108.8688	135.1417	80.559
9	HR	1978	106.3646	136.3605	78.0026

Place	antilog b	growth	a = constant	R square	stderror b
HR	1.01493	1.49292	83.03652	.63149	.00183
UP	1.01507	1.50711	87.99463	.78378	.00124
RJ	1.0078	.78013	96.80109	.22336	.00204

Fig. 7. Estimated TFP

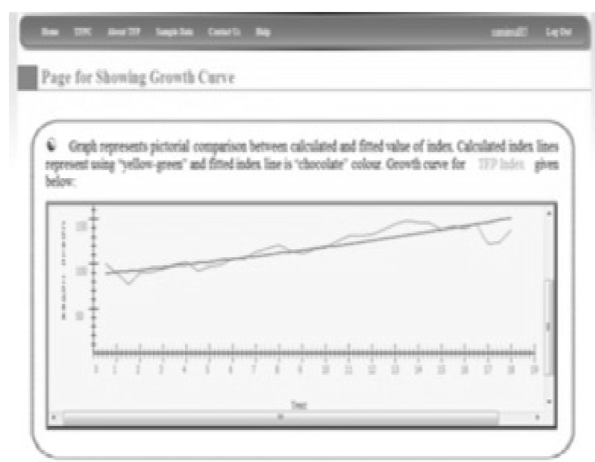


Fig. 8. TFP growth curve

3.1 Single Crop Index

When data is available for any single level (country/state/district) with TFP computational requirement at the same level then there is not much complexity in TFP computation and it can be estimated using EXCEL, TFPIP or WBSTFP. However in a more complex case when data is compiled for spatial units (say district) with requirement of TFP estimation for higher spatial units (say state) then spatial aggregation of data is also inbuilt in WBSTFP. It is a unique feature of WBSTFP which is computationally expensive, time consuming and prone to human errors if done through conventional methods.

3.2 Aggregate Crop Index

Computation of TFP for a sector as a whole requires aggregation of data for many crops within the sector. Further the data for each constituent crop may be available for single spatial unit (say state) or for smaller spatial units (say district) with computational requirement at state level. For the first case crop wise aggregation is required but for latter case crop wise as well as spatial aggregation of data will be required. Facility for both types of aggregation is provided in WBSTFP.

Both single as well as aggregate crop indices modules provide facilities to compute TFP index including output index and input index. In both the modules, aggregation for crops, spatial aggregation of crop data are unique and essential features for computing TFP but are not provided in any of the software including TFPIP. In TFPIP, such tasks are required to be done by the users before using the software.

3.3 Input Data Handling

Input data handling module has been designed and developed for reading uploaded data for computation of TFP. Users can upload their input data through an Excel file which contains three sheets namely Agricultural Production Data sheet (APD), Agricultural Input Data sheet (AID) and Price index data. APD sheet should contain the data regarding spatial units (number of columns depend on the number of spatial levels), year, total value, total production and value of by-product for each crops. Similarly AID sheet should contain the data regarding spatial units (number of columns depending on the number of spatial levels), year, total quantity for each input wherever applicable, total input cost for each input. Price Index data can be provided by the user in Excel sheet. Alternatively, the stored price index will be used for computation. After the data for TFP computation is uploaded and variables and level selection is completed, the TFP computation is done at the server side.

3.4 Output Handling

The estimated total output indices (TOI), total input indices (TII) and total factor productivity indices (TFPI) are presented to the user. The user can download the estimated values in Excel sheets for further analysis. Facilities are provided to generate growth curve of each index. User can get estimated indices for individual spatial units also by selecting the one of interest.

4. RESULTS AND DISCUSSION

To test the accuracy and reliability of the software, manual results of TFP computation using sample data sheet were compared with the TFP computed by using WBSTFP (Table 5). Table 5 shows comparison of TFP

Table 5. Comparison of TFP computation for wheat crop in UP (1987-2006)

Year	TII (WBSTFP)	TII (manual)	TOI (WBSTFP)	TII (manual)	TFP (WBSTFP)	TFP (anual)
1987	0.969	0.969	0.812	0.812	0.838	0.838
1988	1.000	1.000	0.838	0.838	0.837	0.837
1989	0.930	0.930	0.814	0.814	0.876	0.876
1990	0.967	0.967	0.839	0.839	0.867	0.867
1991	0.964	0.964	0.824	0.824	0.855	0.855
1992	0.964	0.964	0.828	0.828	0.860	0.860
1993	0.968	0.968	0.896	0.896	0.926	0.926
1994	0.971	0.971	0.946	0.946	0.974	0.974
1995	0.961	0.961	0.916	0.916	0.954	0.954
1996	0.987	0.987	1.007	1.007	1.021	1.021
1997	0.960	0.960	0.961	0.961	1.001	1.001
1998	0.964	0.964	0.966	0.966	1.002	1.002
1999	1.000	1.000	1.000	1.000	1.000	1.000
2000	1.010	1.010	0.957	0.957	0.948	0.948
2001	0.964	0.964	0.921	0.921	0.955	0.955
2002	0.964	0.964	0.935	0.935	0.971	0.971
2003	0.984	0.984	1.008	1.008	1.024	1.024
2004	1.002	1.002	0.880	0.880	0.878	0.878
2005	1.038	1.038	0.908	0.908	0.874	0.874
2006	1.041	1.041	1.024	1.024	0.984	0.984

of wheat during the period 1987-2005 for UP. Similarly testing was done using the dataset of paddy and maize. The results were comparable and hence it is concluded that software is free from logical errors and the results are reliable.

The software was also demonstrated to stakeholders comprising of agricultural economists and other researchers who either have experience of TFP computation manually or are aware of the intricacies in TFP computation. The software was observed to be a unique tool because of its capability to estimate aggregate crop index. It was anticipated as a useful tool for the students, researchers and policy makers by the group.

5. CONCLUSION

WBSTFP provides online facility to compute reliable TFP subject to accuracy of the input data through a web browser. It can save time by doing complex calculations automatically on its own like crop wise aggregation, spatial aggregation, converting prices to real terms etc. and generating results in understandable format. The software is user friendly and does not demand expertise of computer programming. User can register, login, compute TFP, see results and save result in Excel file for further processing using online client interface. Administrator interface of the software helps in development and maintenance of user database. The results of the software are reliable as per the testing norms.

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