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TOTAL FACTOR PRODUCTIVITY (TFP): THEORY AND APPLICATIONS

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Concept

Total factor productivity is a measure of the productivity of all inputs, or factors of production, in terms of their combined effect on output and is often accounted for by technological change or more efficient methods of producing output.Technological change is the major determinant of long term economic growth and hence Total Factor Productivity growth serves as an indicator of the long-term growth in an economy.

There are different arguments on what total factor productivity actually measures. The conventional view is that TFP measure the rate of technical change (Law (2000) Krugman (1996). Total factor productivity of an economy increases only if more output is produced from a given supply of inputs. Improvements in technology clearly increase total factor productivity.TFP measures all improvements in technology, including such things as the introduction of electricity, motorcar or technological progress leading to increased agricultural output or rapid technological shocks that are associated with information and communications technologies (ICTs). The second argument suggests that TFP measures only externalities and other free gifts associated with economic growth. According to this view, the incomes generated by higher productivity are external to the economic activities that generate growth and these benefits spill over to income recipients not involved in these activities (Jorgenson, 1995).

The basics of total factor productivity measurement- The aggregate production function

Technological progress or growth of total factor productivity is estimated as a residual from the aggregate production function.The aggregate productivity, mean the productivity of unique entities such as nations or entire industries.

Consider the simple Cobb-Douglas version of the aggregate function:

$$Y = AL^{\alpha}K^{\beta}, \alpha + \beta = 1$$

Total aggregate output is measured as *Y. L* is an index of aggregate labour inputs. *K* is an index of aggregate capital. *Y, L* and *K* are independently measured while *A*, α and β are statistical estimations. *A* is an index of the aggregate state of technology called total factor productivity. But changes in the number indicate shifts in the relation between measured aggregate inputs and outputs and in this aggregate model these changes are assumed to be caused by changes in technology (or changes in efficiency and/or in the scale of operations of firms).

The geometric index version of TFP is calculated by dividing both sides of the production function by *L* α. to produce a measure of TFP:

$$TFP = A = \frac{Y}{L^{\alpha}K^{\beta}}$$

The growth rate measure of TFP is then calculated as an arithmetic index generated by taking time derivatives of both sides of the TFP expression. L to the power alpha and K to the power Beta are the shares of output/

income accruing to labour and capital.

$$\alpha = \frac{wL}{Y}$$
$$\beta = \frac{r\,K}{Y}$$

Where w is wages paid to labour, and r is the real rental rate of capital.

$$\frac{wL}{Y} + \frac{r\,K}{Y} = 1$$

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There are some conceptual and empirical problems concerning the measurement of TFP. These relate to the following issues: (1) a relevant concept of capital, (2) measurement of output, (3) measurement of inputs, (4) the place of R&D and public infrastructure, (5) missing or inappropriate data, (6) weights for indices. (7) theoretical specifications of relations between inputs, technology and aggregate production functions, (8) aggregation over heterogeneity.

Approaches to measure TFP

The approaches to total factor productivity measurement are generally classified into frontier and non-frontier approaches. The non- frontier approaches consists of parametric and non- parametric methods. The growth accounting and indexing procedure comes under the non -parametric approach. Programming and econometric approaches are included under the parametric methods (Figure 1).

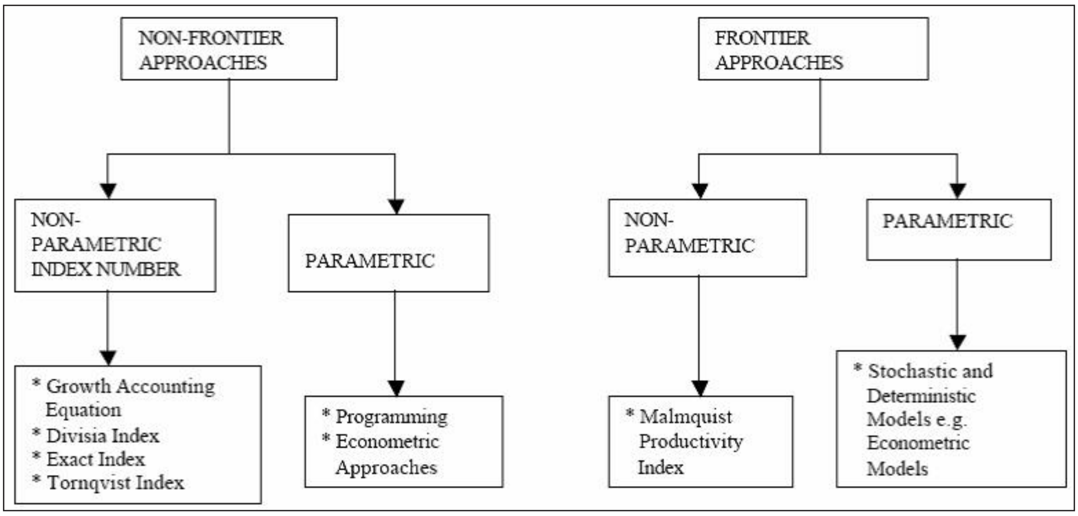

Figure 1. Methodological approaches for TFP measurement: An illustration

There are different indexing methods for calculating the total factor productivity. Some of the most common of these are the Laspeyres index, the Paasche index, the Fisher index and the Tornqvist index. Most work on TFP uses a Tornqvist index, which is basically a percentage change index that averages base and given years weighted indexes. The Tornqvist quantity index is defined as the product across all goods of the ratio of current quantities divided by base year quantities weighted by the average of the base year and current year prices. The Tornqvist index is considered 'superlative' because of its capacity to approximate general functional forms of the production function. Tornqvist index is a discrete approximation to a continuous Divisia index. A Divisia index is a weighted sum of the growth rates of the various components, where the weights are the component's shares in total value. For a Törnqvist index, the growth rates are defined as the difference in natural logarithms of successive observations of the components and the weights are equal to the mean of the factor shares of the components in the corresponding pair of periods. The Törnqvist index represents an improvement over constant base-year weighted indexes, because as relative prices of inputs change, the Törnqvist index allows both quantities purchased of the inputs to vary and the weights used in summing the inputs to vary, reflecting the relative price changes (Lipsey and Carlaw, 2001).

When TFP is calculated from a macro production function, the quantities used are the aggregate capital stock and the aggregate labour supply; when it is calculated from industry data, they will be industry capital and industry labour; similarly for firms, it will be each firm's capital stock and its employed labour. To get the basic quantities without any prior aggregation, extremely detailed micro data would be needed with a separate quantity input for each capital service. Thus, no matter how disaggregated are the physical quantities that are used for any calculation of a TFP index, they are typically aggregated over some group of heterogeneous capital goods (or capital services) by converting them to values. National productivity estimates are of special importance because they are an integral part in public policy making. However at this level of aggregation, the data available are limited to fairly short time series, which limits the scope for econometric estimation. As a consequence, index number methods are most commonly employed for measuring TFP. Most studies have used the index number approach to measure productivity growth due to its simplicity and lower data requirements when compared to complicated econometric models.

Total factor productivity-an application to the marine fisheries sector in Karnataka using Divisia Tornqvist indexing method

TFP index = $\frac{\text{Output index}}{\text{Input index}}$

$$\text{Input index} = \prod_i (X_{it} / X_{it-1})^{(S_{it}+S_{it-1})^{1/2}}$$

Where, X_{it} and X_{it-1} are the quantities of input i at time t and t-1

S_{it} and S_{it-1} are the shares of input i in total cost at time t and t-1

Similarly output index was workout as follows:

$$\text{Output index} = \prod_j (Q_{jt} / Q_{jt-1})^{(R_{jt}+R_{jt-1})^{1/2}}$$

Where, Q_{jt} and Q_{jt-1} are the quantities of resource j at time t and t-1

R_{jt} andR_{jt-1} are the shares of resource j in total revenue at time t and t-1

t is the number of years (Kumar and Jha,2005).

Construction of input and output indices

The total factor productivity indices were developed for marine fishery sector in Karnataka based on the input and output indices calculated for the period 2000 to 2010. Fuel and labour used in the fishery were used for developing the input index. Secondary data on average quantities and prices of inputs in marine fisheries like fuel, labour, and quantities and revenue shares of 18 resource groups for the period 2000-2010 from Central Marine Fisheries Research Institute (CMFRI) was utilized for working out TFP in marine fisheries sector. Compound Annual Growth Rate of TFP index measures the total factor productivity growth for the period under study. The quantity of diesel consumed was obtained from the diesel subsidy given by the department of fisheries, the number of boats operated per year and discussion with fishermen. The labour days were estimated from the number of boats operated per year and the average number of workers in each category of fishing unit.

The fuel used in the fishing industry was estimated based on average fuel consumption per hour of operation for all the fishing units. The data was validated by using total diesel sales data from the different diesel pumps, data from fishermen societies and information on diesel subsidy given by various state departments of fisheries. The data on kerosene was estimated based on the number of motorized units operated per year and average kerosene consumption per fishing trip. Labour employed in the marine fishing industry (Mechanized/motorized/Non-mechanized sectors) was estimated in terms of labour days (Table 1). The fixed capital was estimated from the number of boats and investment details on each category of fishing unit.

Labour used in marine fishing industry was estimated in terms of number of days employed per worker per annum. The labour consists of three categories- mechanized, motorized and non-motorized. The mechanized category included vessels of less than 20 m OAL, which used mechanization both for propulsion as well as for fishing operations. The motorized category consisted of outboard motor fitted boats and non- mechanized category consisted of traditional wooden canoes without any engine.

Table 1. Aggregate quantities of inputs used in marine fish production

States	Total Labour days	Diesel (L)	Kersone (L)
2000	4309039	51638328	4327720
2001	4447234	46628536	4941030
2002	5157142	48682000	6151550
2003	4609297	49383000	5626750
2004	5101818	53162000	7250780
2005	4423243	51858000	6991980
2006	4450965	59813000	4958430
2007	5070005	63060000	7023770
2008	4976950	72988000	10209350
2009	4876358	85000000	9209350
2010	4607594	95000000	7209350

The share of inputs in gross value was worked out based on the assumption that these variables contribute more than 80 percent of the total input cost. The sum of input shares should be equal to 1.The aggregate input quantities were weighted by the inputs shares to develop the input indices for each year.

Similarly output indices were worked out based on the quantities and shares in the total revenue of the resource groups consisting of sharks, catfishes, lizard fishes, perches, croakers, silverbellies, flatfishes, clupeids, ribbonfishes, carangids, pomfrets, mackerels, seerfishes, tunnies, barracudas, shrimps and cephalopods. The TFP index for each year is worked out as ratio of output index to input index expressed as a percentage. The growth in input, output and TFP indices for the period 2000 to 2010 was worked out using compound annual growth rate (Table 2).

Table 2. Estimated input, output and TFP indices of marine fishery sector in Karnataka

Years	Input index	Output index	TFP index
2000-01	100.00	100.00	100.00
2001-02	112.91	129.56	114.74
2002-03	104.65	117.86	112.62
2003-04	115.41	116.81	101.22
20004-05	104.11	156.51	150.32
2005-06	108.94	133.80	122.82
2006-07	121.14	151.32	124.92
2007-08	128.55	173.43	134.91
2008-09	134.85	148.83	110.37
2009-10	136.07	203.58	149.61
CGR	**3.22**	**6.20**	**2.88**

Suggested Readings:

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