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Aggregate Productivity Growth in Indian Manufacturing: An Application of Domar Aggregation

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Foreword

Empirical research on productivity growth in Indian industry is quite extensive. Various estimates show that India is still to attain high rates of productivity growth despite substantive reforms in industrial and trade policies undertaken for over two decades. Therefore, raising productivity levels in manufacturing remains a major policy challenge if Indian industry is to achieve global competitiveness. This study revisits the issue of productivity growth in the manufacturing sectors by addressing the conceptual and data issues in computing aggregate productivity growth. Using a methodology outlined by Domar (1961), the study computes the productivity growth for the aggregate manufacturing sectors from disaggregate levels for the period 1980-2000.

The work is part of on-going research at ICRIER on developing the KLEMS framework for productivity measurement. The analysis, though preliminary, should be of interest to researchers and policy makers.

(Rajiv Kumar)
Director & Chief Executive

July 15, 2009

Abstract

Productivity growth in Indian manufacturing is an important driver of overall growth, yet the issues related to its measurement have still not been resolved. The issue of how to compute an aggregate productivity measure holds significance for two reasons: one, the productivity of a firm should reflect the productivity of the lower levels, which comprise the aggregate; and two, aggregate productivity should also emphasize the importance of inter-industry transactions in an analysis of productivity growth. Contributions from Domar (1961), Hulten (1978) and Jorgenson et al. (1987) have addressed the issue of measuring aggregate productivity. We have made an attempt to compute the aggregate productivity growth using the Domar aggregation technique. Building up from the Total Factor Productivity Growth (TFPG) estimates for 3-digit industries, we have used Domar weights to computed total factor productivity (TFP) growth for selected 10, 2-digit industries for the period 1980-2000. Comparing the estimates based on the Domar aggregation technique with those based on the traditional aggregate value added approach, we observe that the preferred estimates are about half of that obtained by the traditional aggregate value added method. This holds immense significance for any underlying productivity numbers.

***Keywords**: Productivity growth, Domar aggregation, aggregate value added, Indian manufacturing*

***JEL classification**: D24, L6, 047, 053*

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1. Introduction

The realization of productivity growth in the industrial sector continues to drive the overall economic performance of the Indian economy. The Indian economy has now witnessed almost two decades of wide ranging economic liberalization encompassing many sectors. The liberalization of trade and industrial policies was attempted with the sole purpose of making India's manufacturing internally efficient and globally competitive. The industrial productivity performance has shown positive results—from a turnaround in the mid-1980s to improved performance in the 1990s. In this regard, enhancement of India's productivity performance in broad industrial sectors strives to make the manufacturing sector dynamic. Yet, estimates of productivity growth have always raised questions in terms of its magnitude and direction. This is also borne by the fact that the observed productivity growth has remained crucial for policy considerations.

Empirical research on productivity growth in Indian manufacturing is extensive in documenting the productivity performance for the decades of 1960s, 1970s, 1980s and 1990s covering both macro as well as micro aspects of Indian industries. The documented growth rates have shown that by and large the performance of Indian industries has been poor (either a negative rate of productivity growth or an insignificant growth rate of between 1-2 per cent per annum). Overall, the studies on India's manufacturing productivity have been more about documenting the productivity growth for different industries in organized manufacturing at various levels of industries—2 and 3- digit levels of national industrial classifications.

The measurement of productivity growth for Indian industry has mostly used the 'growth accounting' methodology at the aggregate level involving the entire manufacturing sector or its sub-branches. The computation of productivity growth at the aggregate level ignores the fact that industries which form the aggregate often sell a substantial part of their output to one another, thereby overlooking the contribution that each industry makes to the aggregate growth through its own productivity growth rate. Domar (1961) outlined a methodology which takes this into consideration. The Domar aggregation expresses aggregate total factor productivity (TFP) as a weighted sum of the industry's TFP growth and has been used in several studies of productivity (Cao et al. 2007; Gullickson and Harper 1999; Jorgenson et al. 1987; Oulton and O'Mahony 1994).

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Our focus in this paper is to undertake an aggregation technique of computing aggregate productivity growth using industry level productivity estimates. The approach lies in the framework of Domar (1961) which was further developed by Hulten (1978) and Gollop (1979). We derive aggregate productivity growth using industry level productivity growth estimates. The rest of the paper is divided as follows: section 2 lists the methodological issues, particularly the question of 'aggregation' that are important in the context of productivity measurement. Alternative approaches to aggregate productivity measurement are outlined in section 3. The estimates of productivity growth using the Domar aggregation procedure are presented in section 4. The final section provides a conclusion.

2. Measuring Productivity Growth: Some Methodological Issues

Productivity growth estimates of Indian manufacturing have always raised questions in terms of the methodology used. These studies, based as they are on growth accounting, rely on two very heroic assumptions—perfect competition and constant returns to scale. Further, most of the estimates relate to the value added form of the production function rather than the gross output form. In the light of these, there are several methodological issues[1] which merit attention in interpreting TFP growth rates: (1) growth accounting versus econometric estimation, (2) value added versus gross output, (3) measuring intermediate inputs, and (4) aggregation procedure. In this paper, the emphasis is specifically on the aggregation procedure and how this can be used to compute the aggregate TFP growth estimates for Indian manufacturing.

The economic characterization of aggregate productivity growth depends on a society's economic objective for production (Gollop 1983). Solow, Denison and others analyzing aggregate productivity growth reason that goods destined for final demand are the ultimate objective of economic production.[2] The appropriate measure of aggregate output is the sum of sectoral deliveries to final demand. Sectoral deliveries to intermediate demand are excluded from aggregate productivity research as they are viewed as self-canceling transactions.[3] Given this characterization of economic activity, deliveries to final demand can be shown to equal national net output or, as conventionally described, aggregate value added. The result is that studies of aggregate economic performance typically define productivity at the economy level as the efficiency with which labor and capital inputs are converted into aggregate value added. For all their important differences, Christensen and Jorgenson (1973), Denison (1962, 1974, 1979), Jorgenson and Griliches (1967), Kendrick (1961, 1973), Kendrick and Grossman (1980) and Solow (1957) have adopted this conventional approach to aggregate growth accounting.

The deliveries to final demand are certainly an economy's ultimate economic concern for production, the characterization of microeconomic activity, particularly the treatment of intermediate inputs and deliveries to intermediate demand deserves

[1] Das (2001) undertakes a detailed examination of various methodological issues that surround the measurement of productivity growth.

[2] Kendrick (1973) presents the argument clearly—it is the final products included in national products that are the objective of production. These are the goods that satisfy current consumer wants or that add to stocks of productive capacity for satisfying future wants.

[3] Inclusion of intermediate inputs involves double counting, since such inputs have already been included in the final products and the factor services required to produce them are likewise included in total factor inputs.

attention, (Gollop 1979, 1983). The self-canceling property is neither an economic truism nor the result of any particular characterization of society's economic objective. It follows, instead from the assumption that the economy is closed to trade in foreign produced inputs. The intuition underlying this assumption is that the domestic economy's intermediate input equals the sum of domestically produced intermediate goods and foreign supplied materials. Total intermediate input purchases and domestic deliveries to intermediate demand are self-canceling transactions only in an economy importing no intermediate.

The implications for modeling and measuring aggregate productivity growth are two-fold: (1) For an economy closed to trade in imported inputs, intermediate input transactions can be viewed as internal offsetting transfers. Incorporating them into a model of aggregate production involves double counting and therefore the macroeconomic models can suppress the vertically interdependent structure of macroeconomic activity,[4] and (2) With trade in inputs, domestic deliveries to intermediate demand and intermediate input purchases by domestic sectors are neither internal nor offsetting transfers. The aggregate economy cannot be viewed either as a composite of horizontally independent sectors or as an entity independent of foreign producing sectors. The measure of aggregate productivity growth thus importantly depends on the initial descriptions of both the economy's macroeconomic objectives and the technical properties of microeconomic production.

The value added and the final demand specifications of aggregate production are each constrained by different microeconomic models of production.[5] These different characterizations are apparent when defining the aggregate rates of productivity growth formed from sectoral measures of productivity growth incorporating a value added and deliveries to final demand specification. A sectoral model maintaining a value added separability abstract from all inter-sectoral and international transactions and aggregation must capture sectoral advances in productivity transmitted only through value added contributions to aggregate net output. In contrast, in a sectoral model incorporating inter-industry and international transactions, the aggregating algorithm must capture the contributions of each sector's productivity growth through deliveries of its output to both final and intermediate demand.

The value added models both aggregate and sectoral view the economy as a set of horizontally independent sectors. The relevant measure of sectoral output is the quantity of value added. The aggregate economy's production possibilities frontier is defined in terms of the sectoral quantities of value added. Both models consider only labor and capital inputs. The delivery to final demand model of aggregate production and its microeconomic production constraints view the economy as consisting of vertically interrelated sectors depending not only on each other but on international trade as well. Aggregate and sectoral models each define output in terms of its final product. While deliveries to final demand define output at the aggregate level, individual sectors produce output delivered to both final and intermediate demands. Each model considers all inputs primary to its particular production process. While

[4] Gollop (1983) demonstrates that for an economy closed to foreign-produced materials, value added and delivery-to-final-demand models produce equivalent measures of aggregate productivity growth.

[5] Gollop (1983) emphasized the fundamentally different characterization of economic activity represented by value added and delivery-to-final-demand models of economic growth.

labor, capital and imported inputs constitute the economy's primary inputs, sectors employ labor, capital, imported inputs and domestically produced intermediate inputs. Given this vertically integrated mode of economic activity, advances in productivity in an individual sector contribute to aggregate economic growth both directly through deliveries to final demand, and indirectly through increased deliveries to sectors dependent on its output as intermediate input. The aggregation thus captures the direct as well as indirect transmission of sectoral productivity growth.

Aggregate productivity emphasizes the importance of inter-industry transactions into an analysis of productivity growth. This conforms to both sectoral and economy wide principles of economic accounting and production. The inclusion of intermediate input in the sectoral model of production preserves the full integrity of rational producer behavior, and the interdependence of economic activity among microeconomic sectors is explicitly recognized. Further, incorporating intermediate input permits the derivation of the appropriate link between sectoral and aggregate measures of productivity change. The measure of aggregate productivity change derived from a macroeconomic model focusing only on aggregate output and primary inputs can equivalently be derived by appropriately weighting over sectoral measures based on microeconomic models of production that treat capital, labor and intermediate inputs symmetrically.

In the Indian context, Mohan Rao (1996) argues that major studies, namely those by Ahluwalia (1991), Balakrishnan and Pushpangadan (1994) and Goldar (1986) used inappropriate aggregation procedures and the resultant estimates for the aggregate sector are biased. The basic argument centers around the use of an aggregate production function, when output and factor inputs are heterogeneous as is evident when one is dealing with sub-sectors.[6] Therefore, in case of output heterogeneity the ideal procedure would be to compute the TFPG for each sub-sector separately and compute the TFPG for aggregate manufacturing as a weighted sum of the sectoral TFP growth rates. This paper attempts to address this issue by constructing an aggregate measure of productivity growth for selected industries in India's organized manufacturing.

3. Approaches to Aggregate Productivity Measurement

The productivity residual can in principle be computed for every level of economic activity—from the plants to the aggregate economy. The productivity growth residuals are not independent of each other since the productivity of a firm reflects the productivity of its component plants. What about the TFP growth at the higher level of aggregation, for example the manufacturing sector as a whole? It seems that there should be some relationship between productivity growth in the industries of which an aggregate is composed and the productivity growth in the aggregate. Productivity at the aggregate level will increase if productivity in each constituent industry increases

[6] Rao (1996) points out that the production function is the technological relationship between inputs and a homogeneous output with a single price. If heterogeneous outputs have their own distinct technologies, input qualities and input prices, then there exists no production function of the aggregates of such heterogeneous outputs and inputs. Any such aggregate production function will reflect the particular composition of the sub-sector outputs prevalent in a particular year and shifts in this function over time will be an unidentifiable mix of real productivity changes as well as the changing composition of the aggregate output.

or the market share of the high productivity industry increases. A complete picture of the industrial dynamics of an economy would include a mutually consistent measure of TFP residuals at each level in the hierarchy, and of the linkages used to connect levels. Contributions by Domar (1961), Hulten (1978) and Jorgenson et al. (1987) have addressed the theoretical issues in measuring aggregate TFPG in terms of TFPG of the components of the aggregate.

Domar (1961) was the first to work on the aggregate measure of productivity and recognize the complications introduced by the presence of intermediate goods. Plants and firms produce goods and services that are used as inputs in the production processes of other plants and firms.[7] Domar's method of aggregation can be defined as:

$$\mu^{DA} = \sum_i [q_i Y_i / \sum q_i Z_i] \mu_i \tag{1}$$

Where μ_i is the growth rate of TFP for the i^{th} industry. q_i is the price. Y_i is the nominal gross output and Z_i is the nominal final output. Note that μ^{DA} is a weighted sum of the industry TFP growth rates, where the weights are the ratios of nominal gross output of each industry to nominal final output. Final output is that part of an industry's sales which is not destined to be used in the current period by the industries included in the aggregate under study. The weights will clearly sum to more than one, since aggregate gross output exceeds aggregate final output (the sales made within the manufacturing sector are included in the gross output but not in the final output). Domar's weighting scheme is based on the premise that the system of weights is invariant to the degree of integration or aggregation of the economy. The intuition behind the Domar aggregation is that an industry which sells a great deal to others receives a higher weight because high TFP growth in this industry contributes not only directly to aggregate TFP growth but also indirectly through lowering costs elsewhere in the economy.[8]

Hulten (1978) studies the interaction of productivity change and intermediate input. Conventionally measured productivity change tends to mis-state the true impact of the contribution of productivity change to economic growth and the problem lies in the fact that some inputs are themselves an output of the production process. Increased factor efficiency will therefore lead to increased outputs and these in turn will lead to an increase in the quantity of produced inputs. Thus, any assessment of the sources of economic growth must take into account that this induced expansion in produced inputs arises as a result of productivity change. Thus, the growth rate of total factor

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[7] Hulten (2000) addresses this problem as an unpeeling of an onion in order to reach the lower layers of the structures. As each layer is unpeeled the magnitude of these intermediate deliveries gets larger. He further argues that at the level of the aggregate economy because there is only one 'industry' all inter-industry flows cancel out. The inter-industry flows uncancel in passing to the one digit industry level of details.

[8] Gollop (1979) addresses this issue by presenting a heuristic interpretation of the weighting structure. Further, he concludes that the appropriately weighted sum contributions of sectoral productivity growth to aggregate productivity growth are identical whether the sectoral rates are derived from gross-output or value added models of sectoral production. It is also demonstrated that these hold, if and only if, the economy is closed to trade in foreign produced inputs.

productivity must be adjusted for the additional inputs available as a result of the increased factor efficiency.[9]

The expansion in the production of intermediate goods occurring because of increased factor efficiency makes it important to distinguish between the productivity change originating in a sector and the impact of the productivity change on the sector. The latter measures the equilibrium response to shifting sectoral technologies and includes: (1) the induced reallocation of factor input between sectors, and (2) the induced expansion in the intermediate input, which serves to magnify the effect of technical change. Hulten's method of computing the aggregate productivity growth can be written as:

$$\mu^{\mathrm{H}} = \sum_i [q_i Z_i / \sum_i q_i Z_i][\dot{Z}_i / Z_i] - \sum_k [w_k J_k / \sum_k w_k J_k][\dot{J}_k / J_k] \qquad (2)$$

Where Z_i is the final output of the product of the i^{th} industry (i =1,2…… n), q_i is its price, J_k is the kth primary input (k=1,2,…m) and w_k its price (assumed common to all industries). Final output is defined as that part of the industry sales which are not destined to be used in the current period by the industries included in the aggregate under study. Alternatively, final output equals aggregate value added in manufacturing plus aggregate purchases from outside the manufacturing sector. Hulten showed that the aggregate TFP growth rate could be derived as a solution to a maximization problem. If (1) the economy is competitive; (2) for all J, the jth primary factor is paid the same in all industries; and (3) the underlying industry-level production functions are homogenous of degree one, then μ^{H} measures the outward shift of the social production possibility frontier. In calculating μ^{H} an important point of interpretation revolves around the issue of what is to be counted as primary inputs.

Following Jorgenson et al. (1987), the aggregate TFP growth rate is based on calculating aggregate value added, aggregate capital and aggregate labor, and is one that is most often used in practice. The aggregate value added method of computing TFP can be formalized as:

$$\mu^{AV} = [\dot{V}/V] - [P_k K / P_v V][\dot{K}/K] - [P_l L / P_v V][\dot{L}/L] \qquad (3)$$

Where V is aggregate real value added, K is aggregate capital, L is aggregate labor and P_v, P_k and P_l are the prices of value added, capital and labor respectively. The aggregate value added is constructed as a simple sum of the industry level value added$[\mathrm{V} = \sum V_i]$[10] . Aggregate capital and labor are assumed to be translog functions of the different types of capital and labor.

The theoretical problem of how to measure aggregate productivity growth has been solved with certain limitations by the contribution of Domar (1961) and Hulten (1978). Further, the Domar aggregation based TFPG estimates allow for incorporating inter-industry transactions into an analysis of productivity growth. Finally, the

[9] Hulten (1975) takes into account the adjustment for the induced capital accumulation and observes using data from Christenson and Jorgenson's (1969,1970) studies that the adjusted residual is 1.67% per annum and accounting for nearly 64% of the growth rate of output as against the average annual Christenson-Jorgenson residual of 1.42% and 34% respectively.

[10] This equation assumes that the industry level prices of value added P_v are all equal and so can be normalized to one in the base year.

aggregate value added method is strictly appropriate for a closed economy but the estimates of TFPG based on such a measure can lead to serious and misleading conclusions for an economy open to foreign trade in intermediate inputs.

3.1 Aggregate Productivity Growth: Methodology of the Present Study

In this study, the aggregates of concern are 10, 2-digit sectors and the aggregation extends over the respective 3-digit sectors comprising each of the 10 2-digit groups. The computations of the TFP growth for the aggregate (2-digit sectors) are based on the Domar aggregation technique. The aggregate (2-digit sectors) TFP growth rates are obtained as a weighted sum of the respective 3-digit TFP growth rates. The weights are the ratios of nominal industry gross output to aggregate final output. Final output is that part of an industry's sales which is not destined to be used in the current period by the industries included in the aggregate. The weights sum up to more than one as gross output exceeds the aggregate final output. The reason is that gross output for each industry includes sales made within the manufacturing sectors whereas the aggregate final output is net of inter-manufacturing sector transactions.

The intuition behind Domar's weighting scheme for aggregation is: consider an industry which experiences advancement in productivity growth. This particular industry, holding constant all primary and intermediate inputs, can provide the economy with increased output. The objective for creating the appropriate weight for this sector's technological advance is to correctly assign the causal responsibility to this sector for any effect on aggregate technical change. Since the ultimate concern is the effect of this sector's productivity growth change on the aggregate productivity change, the appropriate denominator is the sum of all sectors' contributions to aggregate output net of inter-sectoral transactions, i.e., aggregate final output. Further, since the individual sector transmits the benefits of the productivity growth directly through deliveries to final demand and indirectly through deliveries to intermediate demand, the appropriate weight in the numerator is the sector's gross output, which is the sum of its deliveries to final and intermediate demand.

The Domar measure of aggregate TFP growth [μ^{DA}] is defined as:

$$\mu^{DA} = \sum_i [q_i Y_i / \sum q_i \, Z_i] \mu_i$$

Where μ_i is the TFP growth for the i[th] three-digit industries.[11] Note that μ^{DA} is a weighted sum of the industry TFP growth rates, where weights are the ratios of the nominal gross output of each industry to the aggregate nominal final output. The empirical counterpart to this Domar aggregation based TFP growth is a Tornqvist index:

$$LnTFP(t) - LnTFP(t-1) = {}^1\!/_2 \sum_i \left[\frac{q_i(t) Y_i(t)}{FO(t)} + \frac{q_i(t-1) Y_i(t-1)}{FO(t-1)} \right] \cdot [LnTFP_i(t) - LnTFP_i(t-1)] \quad (4)$$

Where $q_i(t)Y_i(t)$ is the nominal gross output and FO $(t) = \sum q_i \, (t) Z_i$(t) is aggregate nominal final output. The aggregate in the present study refers to a 2-digit industry. The aggregate nominal final output for each 2-digit industry is computed by deducting

[11] The methodology for computing the TFP growth for the individual industries is provided in Annexure 1.

the inter-industry transactions of the 3-digit industries from that of aggregate gross output. The aggregate gross output is defined as the sum of the nominal gross output of the 3-digit industries within a particular 2-digit sector. To arrive at this, we need data on nominal gross output as well as inter-industry transactions according to the 3-digit industries.

The data on nominal gross output by 3-digit industries needed to obtain the aggregate gross output for each 2-digit sector is available from the Annual Survey of Industries (ASI). ASI, however, does not provide data on inter-industry transactions either at the 2 or 3-digit levels of disaggregation. Therefore, we made use of the input-output tables to generate inter-industry transactions at the level of the 3-digit industries. This necessitated establishing a mapping between the I-O sectors and the 3-digit industries. The inter-sectoral flows as provided in the coefficient matrix of the I-O tables were multiplied by the gross output of the respective 3-digit industries to arrive at the inter-industry transaction in value terms. The I-O tables used for deriving inter-industry transactions are given in Table 1.

Table 1: I-O tables used for deriving inter-industry transactions

I-O Table used	The Reference Period
1983-84	1980-81 to 1988-89
1989-90	1989-90 to 1994-95
1993-94	1995-96 to 1997-98
1998-99	1998-99 to 1999-00

Deducting the inter-industry transactions from the aggregate gross output, we arrive at the aggregate final output for each 2-digit industry. The ratio of the nominal gross output by 3-digit industries to the aggregate final output by the 2-digit sector is used as weights for obtaining the productivity growth rate for the 2-digit industries.

We have also attempted to compute the TFP growth rates for the 10 2-digit sectors using the aggregate value added method.[12] The aggregate value added method (Jorgenson et al. 1987) is defined as:

$$\mu_i^{AVA} = [\dot{V}_i/V_i] - w_{ki}[\dot{K}_i/K_i] - w_{li}[\dot{L}_i/L_i],\ i = 1,2,\ldots\ldots\ldots,10$$

Where μ_i^{AVA} represents TFPG for the ith 2-digit sector. V, K and L stands for value added, capital and labor respectively. w_{ki} and w_{li} represents share of capital and labor in value added. The Tornqvist approximation to the aggregate value added TFP growth for sector i is given as:

$$LnTFP_i(t) - LnTFP_i(t-1) = [LnV_i(t) - LnV_i(t-1)] - \bar{w}_{ki}[LnK_i(t) - LnK_i(t-1)] - \bar{w}_{li}[LnL_i(t) - LnL_i(t-1)] \qquad (5)$$

[12] According to Oulton and O'Mahony (1994), the aggregate value added method has no theoretical justification and for a closed economy the method can be shown to be equal to the Domar aggregation methodology. See Gollop (1983) for a demonstration of this proposition. Since the Indian economy in the 1980s was mostly a closed economy, it would be interesting to see if the two methods provide somewhat identical estimates for the 1980s.

Where $\overline{w_{ki}} = {}^{1}/_{2}\,[w_{ki}(t) + w_{ki}(t-1)]$

$\overline{w_{li}} = {}^{1}/_{2}\,[w_{li}(t) + w_{li}(t-1)]$

$w_{ki} = P_{ki}K_i/P_{vi}V_i$

$w_{li} = P_{li}L_i/P_{vi}V_i$

Where P_{ki}, P_{li} and P_{vi} stands for the prices of capital, labor and value added. To implement this method, the aggregate real value added may be measured as a simple sum over the 3-digit industry level value added. We have followed the double deflation method in computing real value added by 3-digit industries. Similarly, aggregate capital and labor have also been built up from industry level estimates.

4. Aggregate Productivity Growth: Estimates for Selected Indian Manufacturing Sectors

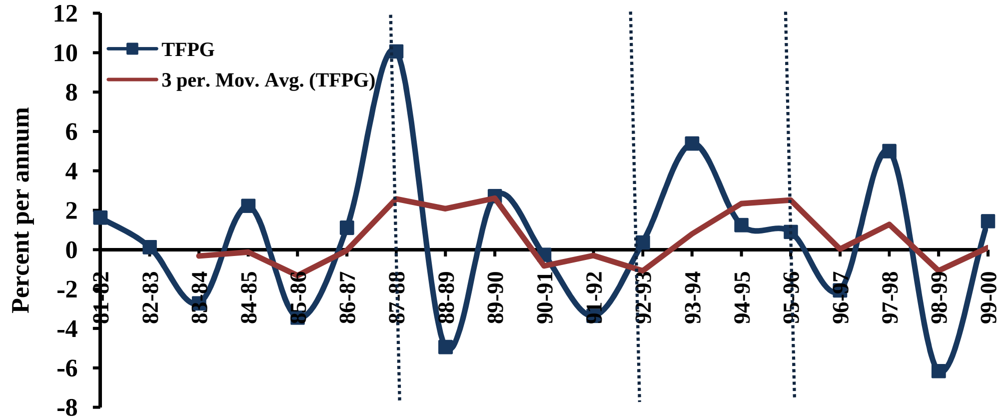
Most TFP growth estimates are either at the level of the whole economy or of broad sectors such as manufacturing. We provide estimates of TFP growth for 2-digit sectors by aggregating up from the 3-digit industry level estimates, using the Domar measure of aggregate productivity growth. This method allows for the contribution of individual industries to aggregate productivity growth via not only reduction in costs to the final consumers, but it also allows for the lowered cost of output which is used by other industries as inputs. Further, an attempt is also made to compare the Domar measure of productivity with the aggregate value added measure, a technique commonly used in studies on measurement of aggregate productivity growth.

The estimates of both the measures of aggregate productivity growth are presented for the period 1980-81 to 1999-2000 and four sub-periods: 1980-81 to 1985-86, 1986-97 to 1990-91, 1991-92 to 1995-96 and 1996-97 to 1999-2000. Further, a comparison is also provided for the two decades—the decade of the 1980s (1980-81 to 1989-90) and the 1990s (1990-91 to 1999-2000).The aggregates of concern in this study refer to the selected 2-digit sectors for which we have industry level estimates. The 10 2-digit sectors are: cotton textiles (23), textile products (26), leather products (29), basic chemicals (30), rubber, plastics etc. (31), basic metals and alloys (33), metal products (34), heavy machinery (35), electrical machinery (36) and transport equipment (37). These sectors account for over 70 per cent of total manufacturing value added.

4.1 Domar aggregation based Productivity Growth: Evidence for the Selected 2-Digit Sectors

The year to year growth rate in productivity for all 10 selected 2-digit sectors shows sharp fluctuations. But looking at the three years moving average growth rate (Chart 1), we observe distinct phases of growth of TFPG. In the 1980s TFPG reached the highest growth in 1987-88 but started declining till 1992-93. The resurgence of TFPG growth after 1992-93 till 1995-96 coincides with the high growth phase of Indian manufacturing in the first phase of the 1990s.

Figure 1: Domar Aggregated TFPG- All Industry Average



Source: Authors' calculations

The industries which followed a similar pattern of growth were cotton textile (23), basic metals and alloys (33), electrical machinery (36) and transport equipment (37) (see annexure 3). The two industries which did well in the last phase were cotton textile (23) and electrical machinery (36).

Table 2 documents the TFP growth rates, growth in value added and output growth along with the value added shares for each of the 10 2 -digit industries.

For the period 1980-85, we observe sharp variation in TFP growth rates across the different 2-digit industries. A majority of the industries exhibit either negative or low positive growth rates in TFP. The industry group of non-electrical and electrical industrial machinery registers a TFP growth rate of less than 2 per cent per annum. The average TFP growth for the five industries that exhibit positive growth in productivity turns out to be around 2.38 per cent, the dominant contribution coming from the leather industry with over 6 per cent per annum growth in productivity. Leather, incidentally is also the sector recording the maximum growth in value added. The sector with the largest share in the aggregate value added, however, records a low growth in productivity (sector 30: 1.85 per cent per annum). The 10-industry average for the TFP growth rate is negative, though the growth in value added is around 3.41 per cent per annum.

The second period of 1986-90 confirming the partial liberalization of the Indian economy shows a marginal improvement as far as the number of sectors recording positive growth in productivity is concerned. Apart from basic chemicals, heavy machinery, electrical machinery and transport equipment, which recorded positive TFP growth in the first period, the cotton textile and textile products industries also improve their performance by recording positive growth rates in excess of 2 per cent per annum. The leather industry, however, records a negative growth rate in this period. The growth in value added for leather is around 5.11 per cent per annum from a high of 24 per cent per annum in the first phase. Four industries record over 10 per cent per annum growth in output. The average TFP growth for the period is around 1.74 per cent per annum and records an improvement over the negative growth observed in the first period.

Table 2: Output Growth, VA Growth and Domar Aggregate TFPG (per cent per annum) by time periods: 2-Digit Industries

NIC 87	23	26	29	30	31	33	34	35	36	37	All Industry Average
Sector	Cotton Textiles	Textile Product	Leather Product	Basic Chemical	Rubber Plastic	Basic Metals	Metal Products	Heavy Machinery	Elect Machinery	Transport Equip	
1980-85											
VA	12.19	1.07	0.65	15.44	5.19	12.90	3.01	8.20	7.61	8.40	74.65
OG	2.11	6.70	12.59	8.17	9.93	3.14	-1.41	6.63	6.16	5.61	5.96
VAG	-4.07	0.75	24.87	7.74	-8.30	3.27	-6.97	10.23	8.32	7.20	4.30
TFPG	-1.81	-2.72	6.31	1.85	-7.05	-0.49	-4.17	1.79	1.15	0.78	-0.44
1986-90											
VA	7.82	1.16	0.62	15.33	9.12	11.21	2.37	7.89	7.42	8.66	71.60
OG	6.44	13.87	8.77	12.43	8.69	8.09	9.66	7.62	12.74	11.18	9.95
VAG	10.00	19.23	5.11	18.44	23.34	10.24	8.74	6.37	17.33	11.04	12.98
TFPG	2.80	2.95	-1.00	6.01	-2.62	2.13	-0.26	0.74	4.29	2.38	1.74
1991-95											
VA	5.74	2.18	1.09	15.96	6.92	10.27	2.63	7.44	9.02	7.57	68.81
OG	3.92	15.83	12.65	8.62	5.19	8.56	9.01	9.08	9.27	14.98	9.71
VAG	5.42	17.73	22.77	7.24	-1.12	10.16	3.94	9.76	10.11	17.98	10.40
TFPG	-0.13	-1.77	8.36	-2.31	-1.75	1.51	-1.02	1.74	0.36	4.15	0.91
1996-2000											
VA	5.07	2.56	0.76	18.83	8.69	11.65	2.43	7.12	6.68	9.24	73.04
OG	2.80	16.58	-1.90	10.18	4.15	2.77	3.79	1.97	14.81	3.01	5.82
VAG	1.146	23.836	-9.117	13.219	26.96	6.487	12.533	5.581	21.937	-0.244	10.23
TFPG	2.79	-0.51	-5.69	-2.13	6.01	1.01	-0.72	-2.16	4.26	-7.29	-0.44
1980-90											
VA	7.35	1.05	0.64	15.31	9.27	12.85	2.48	8.85	7.02	7.48	72.31
OG	4.28	10.28	10.68	10.30	9.31	5.62	4.12	7.12	9.45	8.39	7.96
VAG	2.97	9.99	14.99	13.09	7.52	6.75	0.89	8.30	12.82	9.12	8.64
TFPG	0.49	0.11	2.66	3.93	-4.83	0.82	-2.22	1.27	2.72	1.58	0.65
1990-2000											
VA	4.03	2.62	0.76	19.78	7.70	12.90	2.69	6.95	7.50	8.84	73.76
OG	3.42	16.16	6.18	9.31	4.73	5.99	6.69	5.92	11.73	9.66	7.98
VAG	3.52	20.45	8.60	9.90	11.36	8.53	7.76	7.90	15.37	9.88	10.33
TFPG	1.17	-1.21	2.11	-2.23	1.70	1.29	-0.89	0.00	2.09	-0.93	0.31

***Notes**: 1. Sub-period figures are simple averages of the yearly figures and the all-industry figure is a simple average of the figures for 2-digit industries; 2. OG represents rate of growth of output; 3. VAG represents rate of growth of value added; 4. TFPG stands for productivity growth computed via Domar aggregation method; 5. VA stands for value added share in total manufacturing value added and relates to 1980-81 (Phase 1), 1986-87 (Phase 2), 1991-92 (Phase 3), 1996-97 (Phase 4) and 1985-86 (1980s Phase) and 1995-96 (1990s Phase).*

***Source**: Authors' calculations.*

The third period of 1991-95 saw an increase in the number of industries with negative growth in TFP to five—cotton textile, textile products, basic chemicals, rubber and plastics etc. and basic metals. Our estimates are in line with the pattern of TFP growth at the industry level (Das 2004). Two industry groups—rubber and plastics etc. and metal products have consistently recorded negative growth in TFP for all the three periods. Cotton textiles and leather products were the only industry groups recording TFP growth rates in excess of 2 per cent per annum. The machinery industries, heavy as well as electrical, recorded less than 2 per cent growth rates in TFP. The average TFPG declined from that of the second half of the 1980s.

The final sub-period of the study, 1996-2000, constitutes the period of major economic reforms that were started in the late-1980s and early 1990s. This period along with the earlier ones witnessed major overhauling of the trade and industrial business environment. As expected, we observe an improvement in the TFP growth rates for most of the industry groups. The rubber and plastics etc. group and the electrical machinery industries record large improvements in TFP growth rates over the earlier period. The all-industry average, however, records a decline in TFP growth over the earlier period thereby reflecting the lagged impact of previous regimes.

Table 2 undertakes a comparative evaluation of the two decades of the Indian economy—the decade of the 1980s covering the years 1980-81 to 1989-90 and the decade of the 1990s covering the years 1990-91 to 1999-2000. For the decade of the 1980s we observe a negative TFP growth in two industry groups of rubber and plastics etc. and metal products. For the rest of the industry groups, we observe a TFP growth range of 0—less than 3 per cent with basic chemicals being the only industry group to record a near 4 per cent growth rate in TFP. The machinery and transport sectors together record an average TFP growth rate of nearly 2 per cent per annum. The 1990s saw a decline in TFP across most industry groups. Basic metals along with metal products are the only sectors which show modest improvements in TFP performance. The all-industry average TFP growth shows no improvement in the 1990s over the 1980s. Estimates of the 1990s are in line with other studies (Das 2004, Goldar 2000) which have cited a lowering of TFP growth in the period of the 1990s.

4.2 Productivity Growth or Factor Accumulation?

Table 3 examines the contribution of TFP to growth in output by 2-digit industries for the different periods of the study. The output growth rates are calculated directly from the values at the 2-digit levels. Documenting the productivity contribution across the 2-digit groups, we observe sharp differences across industries as well as across the time periods. The average for the 10 2-digit industries shows that less than 25 per cent of the output growth is accounted for by increases in total factor productivity across the different sub-periods. The contribution, however, increased moderately in the 1990s relative to the 1980s albeit remaining low.

The TFP contribution to output growth for different sub-periods shows wide variations across different 2-digit industry groups. For the period 1980-85, we find six sectors showing positive contributions by TFP growth with the highest contribution coming from metal products (over 200 per cent) and leather products (50 per cent). In the second period of 1986-90 although the number of industries registering positive

Table 3: TFP contribution to Output Growth across time periods: 2-Digit Industries

NIC87	1980-85		1986-90		1991-95		1996-2000		1980-90		1990-2000	
	OG	**TFPC**	**OG**	**TFPC**	**OG**	**TFPC**	**OG**	**TFPC**	**OG**	**TFPC**	**OG**	**TFPC**
23	2.11	-85.92	6.44	43.38	3.92	-3.27	2.80	99.61	4.28	11.51	3.42	34.15
26	6.70	-40.63	13.87	21.23	15.83	-11.20	16.58	-3.05	10.28	1.10	16.16	-7.49
29	12.59	50.12	8.77	-11.35	12.65	66.10	-1.90	299.05	10.68	24.87	6.18	34.19
30	8.17	22.65	12.43	48.33	8.62	-26.84	10.18	-20.96	10.30	38.15	9.31	-23.98
31	9.93	-70.99	8.69	-30.19	5.19	-33.72	4.15	144.94	9.31	-51.95	4.73	35.93
33	3.14	-15.43	8.09	26.31	8.56	17.63	2.77	36.57	5.62	14.63	5.99	21.52
34	-1.41	295.71	9.66	-2.71	9.01	-11.34	3.79	-18.95	4.12	-53.73	6.69	-13.25
35	6.63	27.00	7.62	9.78	9.08	19.14	1.97	-110.06	7.12	17.80	5.92	0.06
36	6.16	18.67	12.74	33.63	9.27	3.84	14.81	28.79	9.45	28.76	11.73	17.84
37	5.61	13.89	11.18	21.27	14.98	27.69	3.01	-242.23	8.39	18.81	9.66	-9.67
Average	**5.96**	**21.51**	**9.95**	**15.97**	**9.71**	**4.80**	**5.82**	**21.37**	**7.96**	**5.00**	**7.98**	**8.93**

Notes: *1. Output growth (OG) is computed using aggregate real gross output of 3-digit values.*
2. TFP contribution (TFPC) is derived from Domar Aggregate measure of TFP.
Source*: Authors' calculations.*

TFP contribution remains the same, the range of the positive contribution lies between 10-50 per cent. For the decade of the 1990s, we find a drop in the number of industries recording positive TFP contributions to three—leather products, electrical machinery and transport equipment. The second half of the 1990s (1996-2000), however, shows some improvements. We observe large contributions from leather products (> 200 per cent), rubber and plastics etc. (<150 per cent) and cotton textiles (around 100 per cent). Comparing the two decades, we observe improvements in the 1990s in these industries—leather products, cotton textiles and basic metals. For the rest of the industry groups, we find that there is a decline in the TFP contribution in the 1990s vis-à-vis the 1980s. Observing the four sub- periods and the periods of the 1980s and the 1990s we note that the expansion of factor inputs accounts for a major part of the observed growth in output across the 2-digit industries. This is in line with our research of TFP contributions at the level of 3-digit industries (Das 2004).

4.3 Aggregate Productivity Growth by Alternative Methods: Domar aggregation versus Aggregate Value added

Despite the lack of theoretical foundation of the aggregate value added method, it is a much- favored approach given its computational simplicity. Table 4 presents the estimates of productivity growth for the 2-digit industries using the aggregate value added method (TA) for the sake of comparison with the Domar aggregation technique. We observe that the estimates of TFPG obtained by the Domar aggregation technique are about half of those obtained by the aggregate value added method. Annexure 4 depicts the graphs of the TA and DA methods for each of the 2-digit industries.

Table 4 presents TFP growth estimates by both Domar aggregation and aggregate value added methods. We find sharp fluctuations in TFP growth rates computed by both the techniques. This holds true for all the industries and, by and large, also for the sub-periods. In some industries the magnitude of differences are over 50 per cent, thereby indicating that the aggregate value added technique presents an overestimation of TFP growth rates. This is due to the fact that the weighting scheme in Domar aggregation considers the ratio of nominal gross output to the aggregate final output. The aggregate final output is computed after netting out inter-industry transactions. Therefore, the estimates of TFP growth based on Domar aggregation reflect the contribution of industries with higher productivity growth to 2-digit TFP growth via aggregate productivity growth directly through its own TFP growth and indirectly via lowering of output costs which is used by other industries as inputs.

Table 4: Aggregate Productivity Growth in 2-Digit Industries: Domar aggregation and Traditional Measurement

NIC87	1980-85		1986-90		1991-95		1996-2000		1980-90		1990-2000	
	DA	**AV**	**DA**	**AV**	**DA**	**AV**	**DA**	**AV**	**DA**	**AV**	**DA**	**AV**
23	-1.81	-4.77	2.80	8.31	-0.13	-0.76	2.79	26.87	0.49	1.77	1.17	11.52
26	-2.72	-4.92	2.95	8.67	-1.77	0.44	-0.51	-3.32	0.11	1.87	-1.21	-1.23
29	6.31	17.47	-1.00	-4.74	8.36	12.97	-5.69	-20.15	2.66	6.36	2.11	-1.75
30	1.85	2.30	6.01	11.14	-2.31	-2.31	-2.13	-1.84	3.93	6.72	-2.23	-2.10
31	-7.05	-14.53	-2.62	13.17	-1.75	-11.09	6.01	13.48	-4.83	-0.68	1.70	-0.17
33	-0.49	-0.92	2.13	5.54	1.51	2.97	1.01	-2.51	0.82	2.31	1.29	0.54
34	-4.17	-11.14	-0.26	0.66	-1.02	-4.61	-0.72	1.40	-2.22	-5.24	-0.89	-1.94
35	1.79	3.76	0.74	2.61	1.74	3.80	-2.16	-4.01	1.27	3.18	0.00	0.33
36	1.15	3.42	4.29	10.15	0.36	2.32	4.26	6.94	2.72	6.78	2.09	4.38
37	0.78	3.31	2.38	7.25	4.15	10.79	-7.29	-15.03	1.58	5.28	-0.93	-0.69

Notes: *1. DA stands for the Domar aggregation technique where each 2-digit TFP growth is a weighted sum of the 3-digit TFP growth rates.*
2. AV stands for the aggregate value added method.
Source: *Authors' calculations.*

4.4 Aggregate versus Non-aggregate TFP estimation: Underestimation or overestimation?

Finally, we undertake a comparison of the different estimates of TFPG at the 2-digit level of Indian manufacturing using the Annual Survey of Industries database. We compare our estimates with that of the specific periods by Ahluwalia (1991), Gangopadhyay and Wadhwa (1998) and Goldar and Kumari (2002).[13] These studies provide estimates at the 2-digit level of aggregation. Our preferred method of computing the aggregate productivity growth for the 2-digit industries by building them up from the TFPG estimates of the 3-digit industries enables us to compare the contribution of the preferred method. We have computed the TFP growth rate based on Domar aggregation for the sub-periods 1980-85 and 1986-90 and the decade of the 1980s. For the first sub-period, our TFPG estimates are compared to Ahluwalia's (1991) study for the period 1979-80 to 1985-86. Gangopadhyay and Wadhwa (1998) provide estimates for the period, 1986–90 and are compared with our estimates for the second sub-period of the study. For the decade of the 1980s and the 1990s (1980-2000) we compare our TFP growth rates with that of Goldar and Kumari (2002) (Table 5).

Comparing our estimates with those of Ahluwalia (1991), we observe that for a majority of the industries, the estimates of TFPG from a value added production function are overestimating the growth in TFP. Leather products and basic chemicals are the only industries where our estimates record a higher TFPG than that of Ahluwalia. Our estimates of TFP growth based on the Domar aggregation method are less than half of those produced by Gangopadhyay and Wadhwa (1998). In particular, we observe that for eight of the ten industries, our estimates are much lower than the corresponding TFP growth estimates of Gangopadhyay and Wadhwa. In only two industries, basic chemicals and metal products, our estimates are higher. Goldar and Kumari (2002) report TFPG estimates for the 1980 and the 1990s. Comparing their estimates with our results shows that for most 2-digit industries, TFPG computed directly from 2-digit data are higher than those obtained by aggregating from the 3-digit industries' TFPG. In only two industry groups, we find that our estimates are higher than those of Goldar and Kumari (2002). For rubber and plastics etc. and metal products, our estimates show negative TFP growth rates against positive and near positive TFP growth rates. It may be important to note that for the rubber and plastics etc. group our estimates have consistently recorded lower growth rates vis-à-vis all the other studies. Thus, we find that our estimates show that the Domar aggregation based TFPG estimates are lower than the other estimates for a majority of the industries in the same time period. While assessing the importance of the preferred method in relation to the estimates of the other three studies, it must be kept in mind that the methodologies underlying these studies are different. Ahluwalia (1991) and Gangopadhyay and Wadhwa (1998) compute TFPG estimates from a single deflated value added production function, whereas Goldar and Kumari (2002) consider a 3-input production function. Our results on the other hand are based on a 4-input production function.

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[13] Ahluwalia (1991) covers the period 1959-60 to 1985-86, Gangopadhyay and Wadhwa's (1998) study extends from 1973-74 to 1993-94 and Goldar and Kumari (2002) covers the period of the 1980s as well as the 1990s, i.e., 1980-81 to 1997-98.

Table 5: Productivity Growth in 2-Digit Industries: Alternative Estimates

NIC87	Time Period	1980-85		1986-90		1980-97	
	Description	Ahluwalia (1991)	Domar Aggregation	Gangopadhyay & Wadhwa (1998)	Domar Aggregation	Goldar & Kumari (2002)	Domar Aggregation
23	Cotton Textiles	0.40	-1.81	6.28	3.17	0.99	0.21
26	Textile Products	n.a.	-2.72	10.80	2.85	0.38	-0.80
29	Leather Products	1.00	6.31	3.91	-1.00	0.12	4.96
30	Basic Chemicals	0.40	1.85	-0.13	3.60	2.32	1.91
31	Rubber & Plastics	2.0 / 27.5	-7.05	5.06	-3.00	1.28	-3.85
33	Basic Metals	-0.5/4.3	-0.49	6.11	1.67	1.41	2.03
34	Metal Products	-2.60	-4.17	-2.49	-0.66	0.40	-1.38
35	Heavy Machinery	1.90	1.79	3.11	0.72	1.72*	1.06
36	Elect. Machinery	3.41	1.15	3.11	2.84		2.24
37	Transport Equipment	1.00	0.78	7.41	2.29	1.89	1.87

Notes: *1. Ahluwalia's (1991) estimates are based on growth accounting from a value added production function and cover the period 1979-80 to 1985-86. Her estimates for 31 and 33 include separately 2.0 for rubber, 27.5 for petroleum, -0.5 for ferrous metals and 4.3 for non-ferrous metals.*

2. Gangopadhyay and Wadhwa's (1998) estimates based on growth accounting from a value added production function and cover the period 1986-90.

3. Goldar and Kumari (2002) estimated the translog index of TFP growth based on the 3-input framework.

4. The Domar aggregation method computes TFPG as a weighted sum of 3-digit industries TFPG.

5. ******* *The productivity estimate is a combination of industry groups 35+36+39.*

Source*: Ahluwalia (1991); Gangopadhyay and Wadhwa (1998); Goldar and Kumari (2002); and authors' calculations.*

5. Summary and Conclusions

Most of the studies on productivity measurement for the Indian industry, particularly the manufacturing sector, document fairly poor growth rates. A reading of the literature reveals that different procedures and data sets have produced quite divergent estimates. It is not possible to state definitively that TFP growth has either decelerated or accelerated. A major debate emerged on the question of 'turn around' in productivity growth at the level of the manufacturing sector in the early 1980s. None of the studies have, however, questioned the traditional procedure of measuring productivity growth.

The TFP residual can, in principle, be computed for every level of economic activity, from plant floor to the aggregate economy. These residuals are not independent of each other, since, for example, the productivity of a firm reflects the productivity of its component plants. Therefore, the productivity at the aggregate should reflect the productivity of the lower levels, which comprise the aggregate. Further, aggregate productivity emphasizes the importance of inter-industry transactions in an analysis of productivity growth. This conforms to both sectoral and economy wide principles of economic accounting and production. The inclusion of intermediate input in the sectoral model of production preserves the full integrity of rational producer behavior and the interdependence of economic activity among microeconomic sectors is explicitly recognized. Contributions from Domar (1961), Hulten (1978) and Jorgenson et al. (1987) have addressed the issue of measuring aggregate productivity. The Domar aggregate method appears to be the most appropriate. We made an attempt to compute the aggregate productivity growth using the methodologically superior Domar aggregation technique. Building up from the TFPG estimates for 3-digit industries, we computed TFP growth for 10 2-digit sectors for the three phases of trade reforms.

Our estimates of aggregate productivity for the selected 2-digit sectors show sharp year to year fluctuations. The average TFP growth displays wide differences for most of the 2-digit industries. The highest TFP growth is recorded by the leather products industry for the periods 1980-85 and 1991-95, whereas during the period 1986-90, basic chemical records the highest growth rate in TFP. Rubber and plastics etc. achieve the highest growth in TFP during the period 1996-2000. Overall, we find that the productivity performance in the 1990s was poor as compared to the 1980s as is evident for the number of industries registering positive growth in TFP.

Comparing the estimates based on the Domar aggregation technique with those based on the traditional aggregate value added approach, we observe that the preferred estimates are about half of that obtained by the traditional aggregate value added method. Hulten and Srinivasan (1999) have observed that estimates based on value added and gross output specifications of the production function are different. They further point out that if the issue at hand involves industrial productivity, then a measure based on a gross output based production function seems more appropriate. The overall conclusion is that the TFPG estimates based on the Domar methodology reflect the contributions of the respective 3-digit industries to the aggregate productivity growth directly through its own TFPG and indirectly via lowering of output costs which is used by other industries as inputs.

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Annexure

Annexure 1: Methodology of TFP growth estimation for the individual 3-digit industries

We consider a set of 3-digit manufacturing industries under each 2-digit manufacturing. Following Jorgenson et al. (1987) we assume that for each industry there exists a production function relating output to labor, capital, materials, energy and time. For the i^{th} industry,

$$Y_i = F^i(L_i, K_i, M_i, E_i, t), \qquad i = individual\ three\ digit\ industries$$

Where Y is real gross output, L is labor input, K is real capital stock, M is real material input, E is real energy input and t is time. TFP growth for the i^{th} industry in year t is calculated using the Tornqvist approximation as:

$$\begin{aligned} Ln[TFP(t)/TFP(t-1)] &= Ln[Y(t)/Y(t-1)] - v_l(t)Ln[L(t)/L(t-1)] \\ &- v_k(t)Ln[K(t)/K(t-1)] - v_m(t)Ln[M(t)/M(t-1)] \\ &- v_e(t)Ln[E(t)/E(t-1)] \end{aligned}$$

Where, $v_l(t) = {}^1/_2\,[v_l(t) + v_l(t-1)]$

$$v_k(t) = {}^1/_2\,[v_k(t) + v_k(t-1)]$$
$$v_m(t) = {}^1/_2\,[v_m(t) + v_m(t-1)]$$
$$v_e(t) = {}^1/_2\,[v_e(t) + v_e(t-1)]$$

v_l , v_k , v_m, and v_e are the averages of the shares of labor, capital, materials and energy for the years (t) and (t-1) as defined above. The methodology assumes perfect competition and constant returns to scale. Further, the revenue shares of the factor inputs sum to unity. The yearly productivity growth rates are computed for each of the individual industries belonging to the 10 selected 2-digit industries. The list of 3-digit industries under each of the selected 2-digit industries is given in annexure 2.

The variables for the estimation of the yearly TFP growth rates are gross output, capital stock, number of workers, materials consumed and energy consumed. The basic source of data used for the productivity estimates is the Annual Survey of Industries (Central Statistical Organization, Government of India). For correcting the reported data on nominal gross output and intermediate inputs, suitable deflators have been constructed with the help of the official series on wholesale price indices (Index Number of Wholesale Prices in India, prepared by the Office of the Economic Advisor, Ministry of Industry, Government of India). For purposes of deflating the material and energy inputs to arrive at the real materials and energy consumed, we needed to create a weighted price index. For this purpose, the appropriate weights were taken from the input-output tables (Central Statistical Organization, Government of India). For estimating the capital input series, estimates of the gross-net ratios to compute the capital stock for the bench- mark years were taken from the 1973-74 Reserve Bank of India (RBI) bulletin. The deflator for the capital stock series was computed from the yearly volumes of the National Accounts Statistics (Central Statistical Organization, Government of India).

Annexure 2: List of Industries under each 2-digit industry group

2-digit-NIC87	2-digit industries description	3-digit-NIC87	3-digit industries description
23	Cotton Textile	230	Cotton Ginning, Bailing & Cleaning
		231	Cotton Spinning other than Mills
		232	Weaving & Finishing of Cotton Khadi
		233	Weaving & Finishing of Cotton- Handloom
		234	Weaving & Finishing of Cotton- Powerloom
		235	Cotton Spin/Weave/Proc in Mills
		236	Printing of Cotton Textiles
26	Textile Products	260	Knitted or Crochted Textiles
		262	Threads, Cordage, Ropes, Twines etc.
		263	Blankets, Shawls, Carpets & Rugs
		265	Textile Garments & Accessories
		267	Made-Up Textiles
		268	Water Proof Textile Fabrics
		269	Textile Products, Nec
29	Leather and Leather Products	290	Tanning, Curing, Finishing of Leather
		291	Leather Footwear
		292	Apparel of Leather & Substitutes
		293	Leather Products & Substitutes
		299	Leather & Fur Products, Nec
30	Chemicals and Chemical Products	300	Organic & Inorganic Chemicals
		301	Fertilizer & Pesticides
		302+306	Synthetic Rubber & Manmade Fiber
		303	Paints, Varnishes & Products
		304	Drugs & Medicines
		305	Perfumes, Cosmetics & Lotions
		307	Safety Matches
		308	Explosives & Fireworks
		309	Chemical Products, Nec
31	Rubber, Plastics, Petroleum etc.	310	Tyres & Tubes
		311	Rubber & Plastic Footwear
		312	Rubber Products, Nec
		313	Plastic Products, Nec
		314	Refined Petroleum Products
		316	Refined Petroleum Products, Nec
		318	Coke-Oven Products
		319	Other Coal/Tar Products
33	Basic Metals and Alloys	330	Iron & Steel in Primary/Semi-primary
		331	Semi-finished Iron & Steel
		332	Ferro-Alloys
		333	Copper Manufacturing

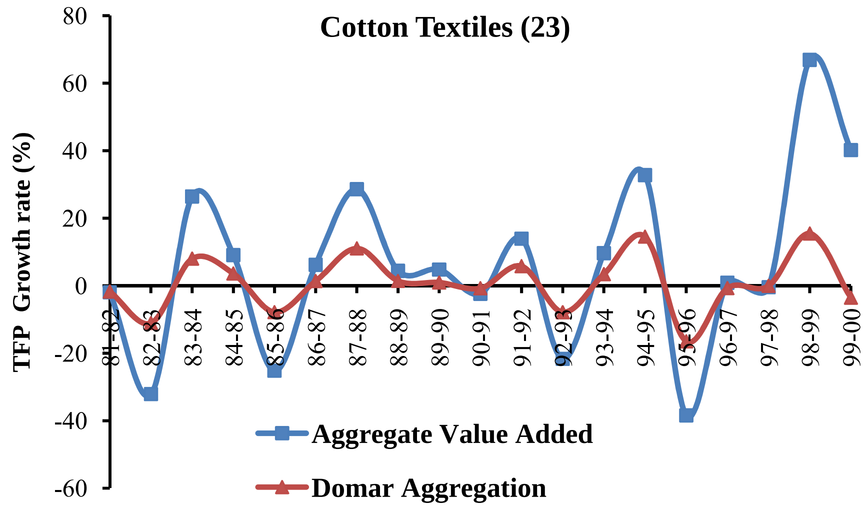
2-digit-NIC87	2-digit industries description	3-digit-NIC87	3-digit industries description
		334	Brass Manufacturing
		335	Aluminium Manufacturing
		336	Zinc Manufacturing
		338+339	Metal Scraps & Non Ferrous Metals
34	Metal Products	340	Fabricated Structural Metal Products
		341	Fabricated Structural Metal Products, Nec
		342	Furniture & Fixtures
		343+349	Hand Tools, Weights etc.
		344+345	Metal Prods & Stamping/Forging of metals
		346	Metal Kitchen Ware
35	Non Electrical Machinery and Parts	350	Agr Machinery, Equipments & Parts
		351	Constr/Mining Machines & Equipment
		352	Prime Movers & Boilers
		353	Food & Textile Machinery
		355	Refrigerators & Air conditioners
		354	Other machinery
		356	General Purpose Machinery
		357	Machine Tools, Parts & Accessories
		358	Office & Computing Machines
		359	Special Purpose Machinery
36	Electrical Machinery and Parts	360	Electrical Industrial Machinery
		361	Wires & Cables
		362	Cells & Batteries
		363+364	Electric Lamps, Fans & Domestic Appliances
		365+366	Radio & TV Apparatus
		368	Electronic Valves &Tubes etc.
		369	X-Ray Machines & Electrical Equipment ,Nec
37	Transport Equipment and Parts	370	Ships & Boats
		371	Locomotives & Parts
		372	Wagons & Coaches
		373+374	Motor Vehicles, Cars & Products
		375	Motorcycle, Scooter & Products
		376	Bicycles & Parts
		377	Aircraft & Related Products
		379	Transport Equipment, Nec

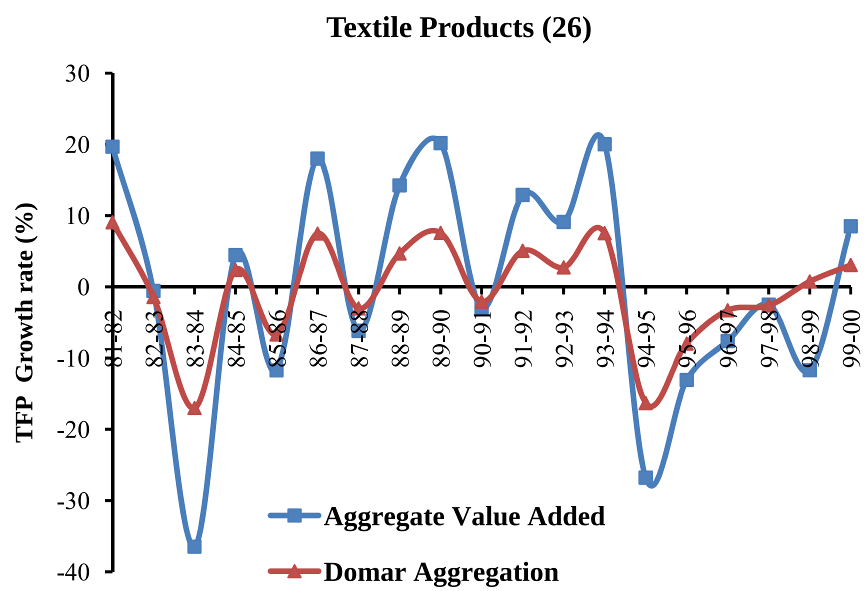
Annexure 3: Yearly growth rates of Domar aggregate TFP: Selected 2-Digit Industries

Code	**23**	**26**	**29**	**30**	**31**	**33**	**34**	**35**	**36**	**37**	**All**
Sector	*Cotton Textiles*	*Textile Product*	*Leather Product*	*Basic Chemical*	*Rubber Plastic*	*Basic Metals*	*Metal Products*	*Heavy Machinery*	*Elect Machinery*	*Trans Equipment*	*Industry Average*
81-82	-1.76	9.08	16.12	2.30	-27.42	1.90	4.42	3.78	2.00	5.88	1.63
82-83	-11.07	-1.41	4.62	-0.42	-0.57	19.59	-17.85	3.18	1.09	4.13	0.13
83-84	8.00	-16.99	-5.78	10.59	-10.15	-14.80	2.65	-1.78	3.67	-2.59	-2.72
84-85	3.61	2.38	8.97	2.04	5.49	-4.64	-4.96	7.11	2.25	0.03	2.23
85-86	-7.84	-6.67	7.60	-5.25	-2.58	-4.48	-5.11	-3.34	-3.25	-3.55	-3.45
86-87	1.37	7.50	4.27	-0.85	-6.58	1.95	1.46	-1.65	1.05	2.63	1.12
87-88	11.04	-3.01	11.98	10.48	-2.12	5.30	6.37	2.01	8.29	50.29	10.06
88-89	1.40	4.70	-21.24	10.23	-3.04	9.42	-2.06	-2.06	-1.05	-45.66	-4.94
89-90	0.93	7.59	7.28	-6.19	7.62	-8.47	-3.38	7.12	12.75	1.94	2.72
90-91	-0.76	-2.06	-7.26	16.37	-8.99	2.45	-3.69	-1.70	0.39	2.69	-0.26
91-92	5.77	5.08	7.96	-8.03	-8.15	-22.69	1.88	-7.09	-4.78	-3.49	-3.35
92-93	-7.86	2.75	12.85	0.12	-3.93	7.80	-9.63	-2.36	0.86	3.12	0.37
93-94	3.41	7.56	15.12	-0.65	1.77	9.65	4.95	6.21	0.19	5.67	5.39
94-95	14.53	-16.31	2.86	-7.34	0.02	10.17	-0.49	1.95	4.22	2.91	1.25
95-96	-16.49	-7.95	3.00	4.34	1.54	2.62	-1.81	9.98	1.29	12.53	0.90
96-97	-0.71	-3.27	5.15	0.09	-8.58	-4.40	-1.20	-1.62	-2.50	-3.57	-2.06
97-98	-0.03	-2.61	10.89	4.59	0.31	23.16	5.06	-1.80	11.64	-1.16	5.00
98-99	15.46	0.78	-19.25	1.48	-11.99	-20.98	2.57	-6.40	-3.04	-20.20	-6.16
99-00	-3.55	3.08	-19.56	-14.69	44.30	6.28	-9.30	1.16	10.96	-4.22	1.45

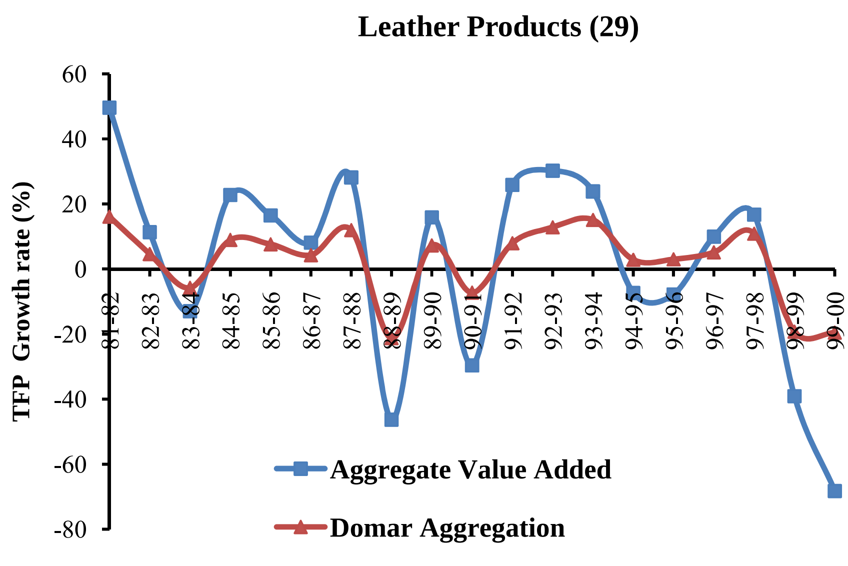
Notes: *1. TFP growth rates are calculated using the Domar aggregation method.*
2. Average TFP growth rate is computed as a simple average of 2-digit TFP growth rates.
Source: *Authors' calculations.*

Annexure 4: Aggregate Productivity Growth in 2-Digit Industries: Domar and Traditional Measures

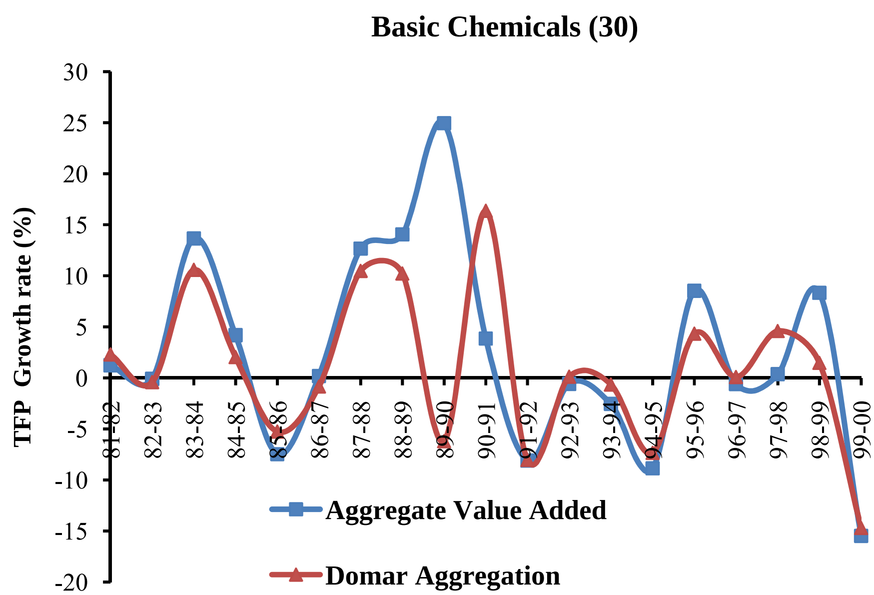


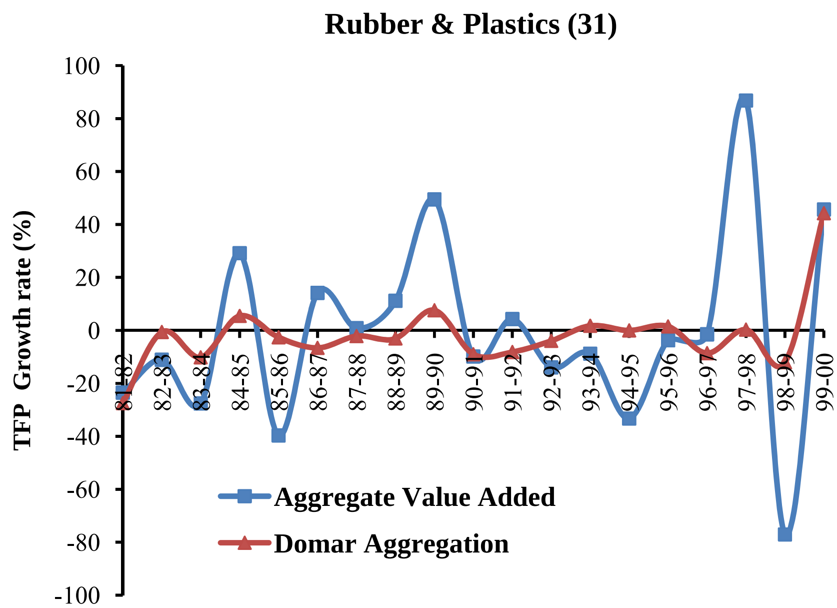


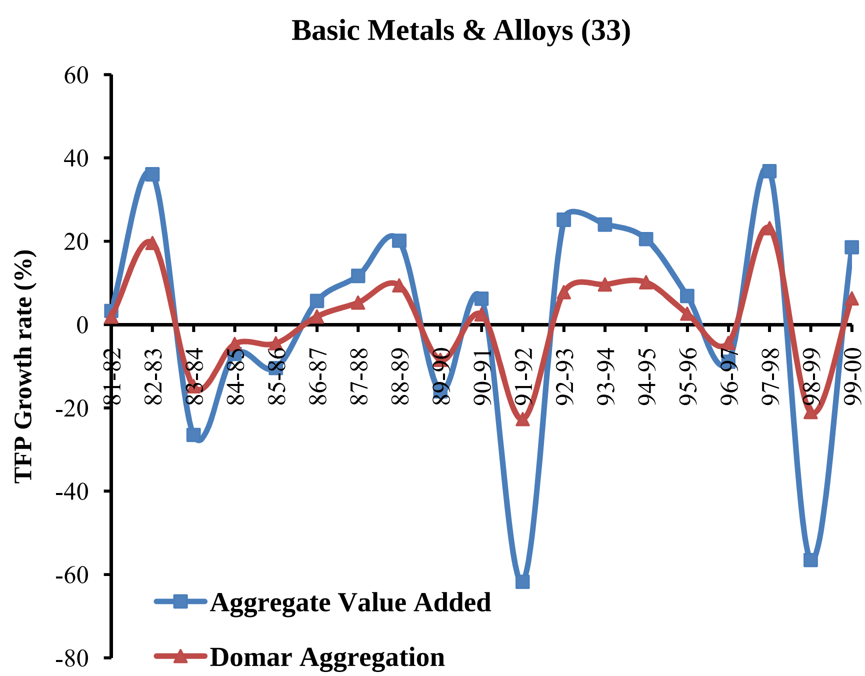
Leather Products (29)

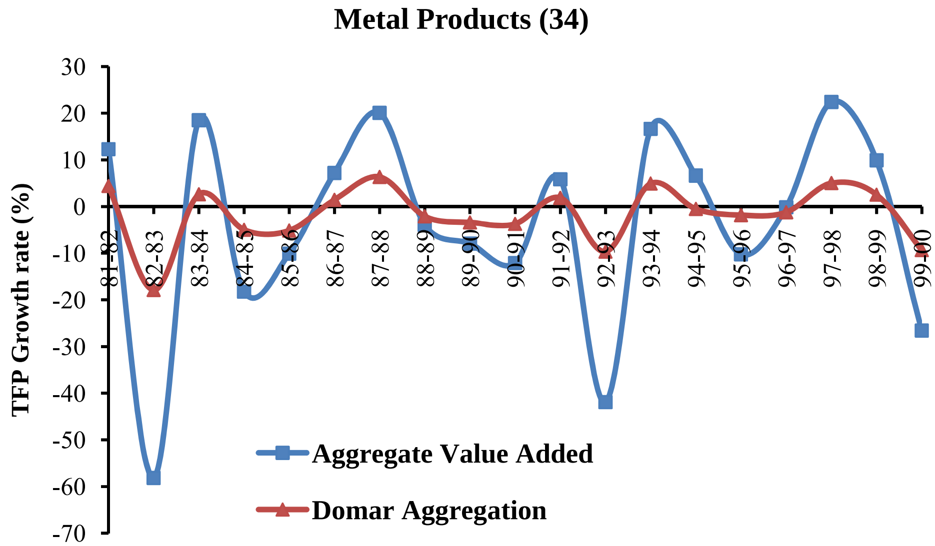


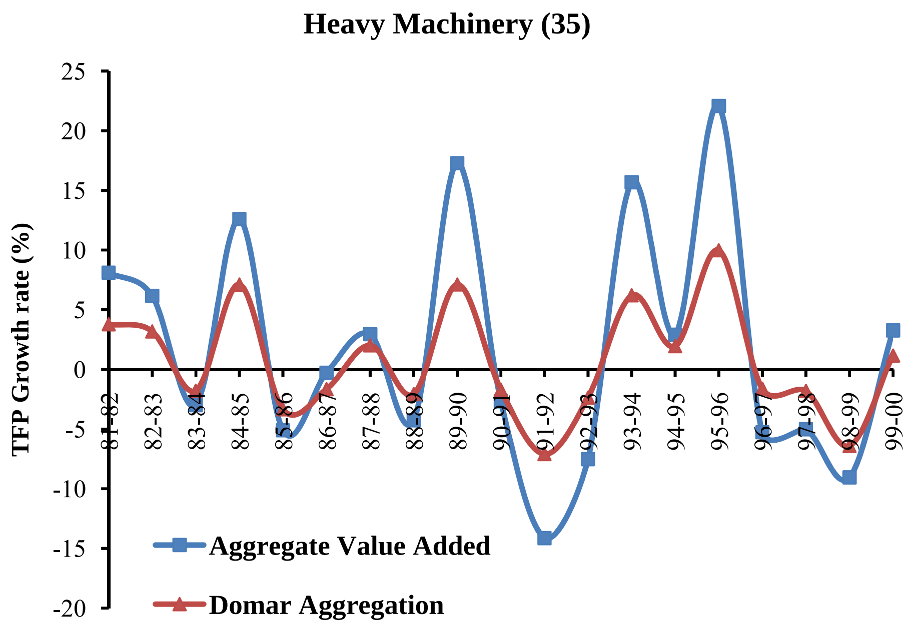
Basic Chemicals (30)

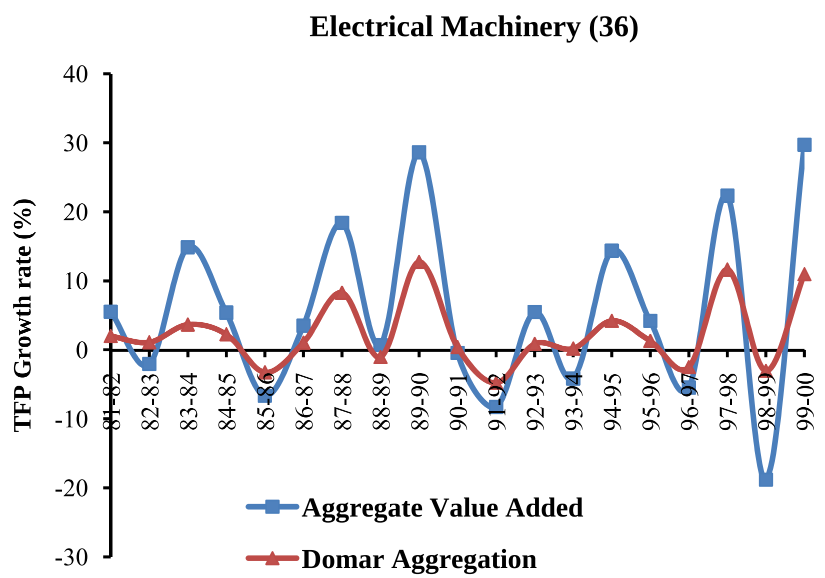


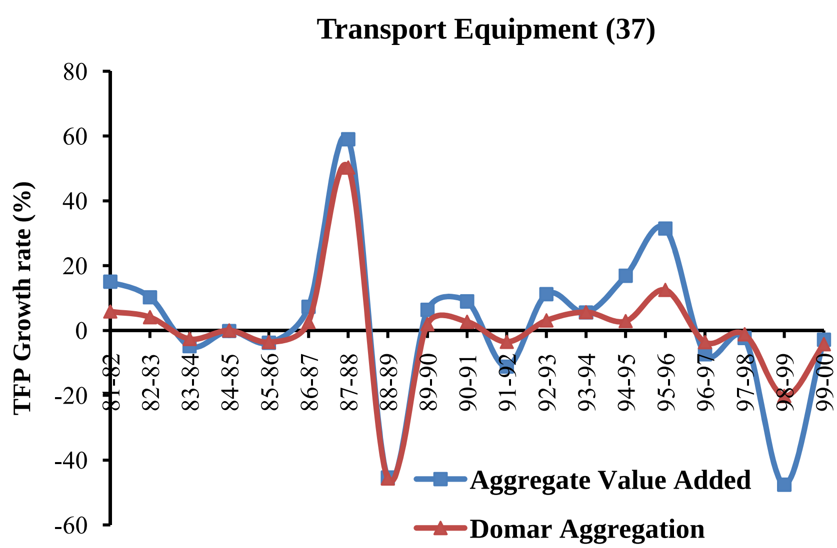

Rubber & Plastics (31)
TFP Growth rate (%)
100
80
60
40
20
0
-20
-40
-60
-80
-100
81-82
82-83
83-84
84-85
85-86
86-87
87-88
88-89
89-90
90-91
91-92
92-93
93-94
94-95
95-96
96-97
97-98
98-99
99-00
Aggregate Value Added
Domar Aggregation


Basic Metals & Alloys (33)
TFP Growth rate (%)
60
40
20
0
-20
-40
-60
-80
81-82
82-83
83-84
84-85
85-86
86-87
87-88
88-89
89-90
90-91
91-92
92-93
93-94
94-95
95-96
96-97
97-98
98-99
99-00
Aggregate Value Added
Domar Aggregation


Metal Products (34)
TFP Growth rate (%)
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
81-82
82-83
83-84
84-85
85-86
86-87
87-88
88-89
89-90
90-91
91-92
92-93
93-94
94-95
95-96
96-97
97-98
98-99
99-00
Aggregate Value Added
Domar Aggregation


Heavy Machinery (35)
TFP Growth rate (%)
25
20
15
10
5
0
-5
-10
-15
-20
81-82
82-83
83-84
84-85
85-86
86-87
87-88
88-89
89-90
90-91
91-92
92-93
93-94
94-95
95-96
96-97
97-98
98-99
99-00
Aggregate Value Added
Domar Aggregation


Electrical Machinery (36)
TFP Growth rate (%)
40
30
20
10
0
-10
-20
-30
81-82
82-83
83-84
84-85
85-86
86-87
87-88
88-89
89-90
90-91
91-92
92-93
93-94
94-95
95-96
96-97
97-98
98-99
99-00
Aggregate Value Added
Domar Aggregation


Transport Equipment (37)
TFP Growth rate (%)
80
60
40
20
0
-20
-40
-60
81-82
82-83
83-84
84-85
85-86
86-87
87-88
88-89
89-90
90-91
91-92
92-93
93-94
94-95
95-96
96-97
97-98
98-99
99-00
Aggregate Value Added
Domar Aggregation

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