Did Trade Liberalization Boost Total Factor Productivity Growth in Manufacturing in India in the 1990s?

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Abstract

India undertook substantial trade reforms from 1991 onwards, accompanied by extensive industrial reforms. Several studies undertaken to date based on growth accounting have reported that total factor productivity (TFP) growth in Indian manufacturing in the initial seven to ten years of the post-reform period was lower than that in the decade before the reforms. This finding is in sharp conflict with the sizeable econometric literature that has unambiguously established a positive effect of trade reforms on productivity, backed by strong theoretical reasons to expect such an effect. This article asserts that certain corrections are required in the computation of TFP growth in Indian manufacturing for the 1980s and 1990s for making a valid comparison and presents the corrected TFP growth rates. Further, an argument is built theoretically with some preliminary empirical support that a downward estimation bias is likely to arise when the conventional growth-accounting approach to the measurement of TFP growth is applied to a situation when major trade reforms are underway, as was the case with Indian manufacturing in the 1990s. Based on the TFP growth estimates obtained, a supportive plant-level analysis of the impact of tariff reform on productivity of Indian manufacturing plants, and the identified possible downward bias in TFP estimation, it is argued that in all probability the productivity growth performance of Indian manufacturing was better in the 1990s following the reforms than the performance in the 1980s.

There is a sizeable econometric literature on the impact of trade liberalization on productivity in manufacturing in emerging economies based on firm-level or plant-level data.[2] Being based on firm- and plant-level panel data, these studies have a clear

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2 See, for example, Pavcnik (2002); Schor (2004); Fernandes (2007); Amity and Konnigs (2007); Hu and Liu (2014); and Jongwanich and Kohpaiboon (2017).

methodological advantage in ascertaining the effect of trade liberalization on productivity (as against a simple comparison of productivity growth rates between pre- and post- reform periods based on growth accounting). The inference one may draw based on this literature is that trade liberalization significantly enhances productivity in manufacturing firms and manufacturing plants in emerging economies.

There is a similar body of literature for Indian manufacturing, dealing with the impact of trade liberalization on manufacturing sector productivity, which is the theme of this article.[3] The findings of these studies indicate that India's trade liberalization had a positive effect on productivity in Indian manufacturing. This conclusion finds additional support and strength from the findings of the econometric studies undertaken at the industry-level, also showing a positive effect.[4]

Notwithstanding the strong empirical basis that the above mentioned studies provide for expecting trade liberalization to yield substantial productivity gains for the manufacturing sector, India's experience has been quite different, at least apparently so, and this makes an interesting case to study. India is the largest emerging economy after China and had a highly restrictive trade regime by the end of the 1980s. The tariff rates in India were among the highest in the world and there were extensive quantitative restrictions on imports of varying degrees of strictness. In 1991, a process of major trade liberalization began in India. In the course of the following 10 years, substantial trade liberalization took place and manufacturing productivity growth did not move in the way expected.

To elaborate on India's economic reforms, the liberalization of its international trade regime that India made from 1991 onwards involved, the removal of quantitative restrictions (QRs) on imports and a huge reduction in tariff.[5] These developments in turn helped in removing the anti-export bias prevailing in the pre-reform period. Along with trade liberalization, extensive reforms were carried out in industrial policy and related aspects such as foreign direct investment.[6] These reforms were however not accompanied by any significant pick-up in the growth rate in total factor productivity (TFP) in manufacturing (to be more specific, organized manufacturing). Rather, there was a fall. This is the impression one would gather from the estimates of TFP growth in Indian manufacturing available for the 1980s and 1990s in

3 See Krishna and Mitra (1998), Natraj (2011), Topalova and Khandelwal (2011), Ahsan (2013), Harrison *et al.* (2013), Gupta and Veeramani (2015a), Mukherjee and Chanda (2020) and Goldar *et al.* (2020).

4 See Chand and Sen (2002), Goldar and Kumari (2003), Das (2006, 2016), Ghosh (2013), and Rijesh (2019).

5 For discussion on trade and tariff reforms, see Nouroz (2001), Goldar (2002), Das (2003a, 2003b), Panagariya (2004a), Virmani *et al.* (2004), Pursell *et al.* (2007), Banga and Das (2012), Das (2016) and Singh (2017), among others.

6 See Joshi and Little (1996), Ahluwalia (2002), Bajpai (2002), Das (2003b), and Panagariya (2004b), among others.

quite a few studies.[7] This is indeed a matter of surprise because economic reforms are expected to boost TFP growth in the industrial sector for the reasons explained below.

The domestic industrial and trade reforms are expected to lead to an increase in the rate of TFP growth in manufacturing through various channels.[8] The reforms are expected to put pressure on domestic producers to improve resource-use efficiency. The reforms are also expected to create conditions that will force the removal of the inefficient producers from among the domestic producers (or contraction in the market share of such producers) and help the efficient producers to thereby capture a larger share of the market and the average efficiency in the industry goes up.[9]

In addition to these, reforms are expected to contribute to productivity in various other ways including gains in productivity arising from increased access to imported intermediate inputs[10] and capital goods. But these arguments, though based on sound theory, did not meet the expected outcomes – this is the sense one would obtain based on the findings of most studies on TFP growth in Indian manufacturing based on growth accounting. It appears therefore that the beneficial forces unleashed by trade and industrial reforms did not materialize into an accelerated TFP growth in Indian manufacturing in the 1990s. Is this true?

Why the economic reforms failed to result in a marked increase in the TFP growth rate in Indian manufacturing in the 1990s is an intriguing question. It has received the attention of scholars writing on productivity in Indian manufacturing. One explanation is the J-curve hypothesis of productivity and growth (Virmani and Hashim, 2011). The argument is that in the initial phase of economic reforms, there was obsolescence of skill, capital and technology in some industries, sub-sectors and sectors. Thus, a portion of the employees in Indian manufacturing had to be directed to retraining and re-skilling and a part of capital assets became obsolete and had to be replaced, and it is only over time that Indian manufacturing could overcome these developments. This is the reason why there was a sharp increase in the growth rate in TFP after 2003, reflecting lagged effect of economic reforms.

At its core, this article is concerned with

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7 See, for instance, Trevedi, *et al.* 2000; Goldar and Kumari, 2003; Goldar, 2006; Banga and Goldar, 2007; Virmani and Hashim, 2011; and Trevedi *et al.* 2011; for a review of studies, see Goldar, 2014; the estimates of TFP growth in these and other studies are shown later in Table 1. Bollard *et al.* (2013), however, have reported a significant increase in the growth rate of TFP in Indian manufacturing during 1993 to 2007 in comparison with the TFP growth rate during 1980 to 1992. In terms of the methodology adopted, this study was quite different from the ones listed above. Another study that reported an increase in the TFP growth rate in Indian manufacturing in the post-reform period in comparison with the pre-reform period is Unel (2003). See Goldar (2004) and Goldar (2014) in this context.

8 See Topalova and Khandelwal (2011), Rijesh (2019) and Goldar, *et al.* (2020), among others.

9 Interestingly, the estimates of Bollard *et al.* (2011) for relatively bigger plants within Indian manufacturing indicate that reallocation did not contribute more to TFP growth in the post-reform period than in the pre-reform period.

10 See Goldberg *et al.* (2010) for an analysis of how improved access to imported intermediate inputs contributed to productivity growth in Indian manufacturing in the post-reform period.

the effect of economic reforms, particularly trade reforms, on TFP growth in Indian manufacturing. An important focus is on TFP estimation methodology. The article points out certain inaccuracies in the manner TFP growth in Indian manufacturing has been commonly computed in many previous studies that have applied the growth accounting methodology based on ASI (*Annual Survey of Industries*)[11] data and made a comparison of the manufacturing sector TFP growth rate between the pre- and post-reform periods.

In addition, the article addresses the issue of an estimation bias that is inherent in the measurement of TFP growth when the conventional growth accounting methodology is applied to industries of a highly protected developing economy undergoing substantial trade liberalization. This was the situation faced by Indian manufacturing in the 1990s. An argument is advanced that due to the collective effect of the aforementioned inaccuracies in TFP measurement and the identified bias, the measured TFP growth in many of the studies undertaken in the past, may have failed to capture properly the improvements in TFP in manufacturing that took place in the first decade of the post-reform period. To correct the measurement inaccuracies and show their significance, a new set of TFP growth estimates with and without corrections are presented in the article.

As regards the bias in the TFP growth measurement noted earlier, it is difficult to provide empirical content for this line of argument. Nonetheless, an attempt is made to put forward some empirical evidence, even if sketchy, in support of the argued estimation bias in TFP growth measurement. These computations and pieces of evidence when seen along with the figures on conventionally measured TFP growth will help in making a better assessment of the impact of trade and industrial reforms on TFP growth in Indian manufacturing in the 1990s.

The main part of the analysis is based on data on the aggregate organized manufacturing sector and panel datasets at the industry level. This is supplemented by another piece of research in which econometric analysis is carried out of the impact of tariff reductions on productivity using plant-level data for Indian manufacturing for the years 1998-99 to 2010-11.[12] The aim is to gain a better understanding of the issue under investigation.

The article is organized as follows. Before going into the productivity trends, an examination of the trends in the import-penetration ratio is done in section 1. The estimates of TFP growth in Indian manufacturing (organized segment) presented in various earlier studies are taken up for discussion in section 2. Certain inaccuracies on TFP measurement are pointed out and corrections are made in this section. In section 3, an attempt is made to provide empirical content to the theoretical argument that a downward bias may arise in the mea-

11 Annual Survey of Industries, National Statistical Office, Ministry of Statistics and Programme Implementation, Government of India.

12 These are financial years, from April 1 to March 31 of the following year. Thus, 2008-09 means, April 1, 2008 to March 31, 2009, similarly for other financial years.

surement of TFP based on growth accounting in a situation of ongoing trade reforms. Section 4 is devoted to an analysis of the effect of trade liberalization on manufacturing productivity based on plant-level data. Finally, the key conclusions of the study are summed up in section 5.

Trends in Import Penetration Ratio

To begin the discussion, the following question may be asked: did trade liberalization of the 1990s (and later) lead to a substantial hike in import competition faced by domestic producers of manufactured goods in India, resulting in a marked increase in the import penetration ratio?[13] What does the available data on import penetration tell us on this point?

According to the estimates made by the present author (computation and data sources explained in Goldar, 2022), the import penetration ratio in Indian manufacturing (excluding petroleum products) was about 9 per cent in 1990-91 and it rose only by 3 percentage points between 1990-91 and 1998-99. Going by the estimates made by Das (2016: 21), the import penetration ratio in manufacturing increased from about 10 per cent in 1990-91 to about 15 per cent in 2009-10. It is, however, important to note that it was lower in 1996-97 than in 1990-91.

The quantitative restrictions (QRs) on imports of intermediate and capital goods were mostly removed in the 1990s, but the QRs on a large section of consumer goods continued during most of the 1990s and QRs were only removed in 2000 and 2001. Thus, the trends in import penetration should be seen for intermediate goods and capital goods separately from consumer goods. For intermediate goods, Das (2016: 36) finds that the import-penetration ratio rose only by a couple of percentage points between 1990-91 (when it was about 11 per cent) and 1996-97, and then it came down, with the result that the import penetration ratio for intermediate goods in 1999-2000 was almost the same as that in 1990-91. By and large, the same was the trend in import penetration ratio in capital goods – it was about 16 per cent in 1990-91, there was a slight increase till 1996-97 and then a fall – the figure for 1999-2000 was only slightly higher than that for 1990-91.

The removal of QRs on imports of manufactured products took place along with a substantial lowering of tariff rates on imports. The tariff rates in India by the end of the 1980s were very high, one of the highest in the world, and with the initiation of trade reforms coupled with industrial reforms, the tariff rates were cut substantially. According to Pursell *et al.* (2007),[14]

13 The import penetration ratio is defined as imports divided by availability, where availability is equal to domestic production plus imports minus exports (Das, 2016:19).

14 According to the data on tariff rates provided by Pursell *et al.* (2007), the collection rate of duty in 1991 was about 60 per cent of the value of imports. This probably also includes countervailing duty (equal to excise duty on domestic products) and thus the protective component of actual customs duty paid was lower than 60 per cent. Nouroz (2001) reports that in 1992-93 the average tariff rate across manufacturing industries was about 92 per cent and the collection rate was about 46 per cent. These two rates fell to 35 per cent and 28 per cent respectively by 1997-98

the average industrial tariff fell from 130 per cent in 1991 to about 40 per cent by the end of the 1990s. Somewhat similar figures on tariff rates on industrial products have been reported by Das (2016:24).[15] According to Nouroz (2001) the import-weighted average tariff for manufactured goods was 90.5 per cent in 1987 which came down to 38 per cent in 1994 and further down to 30 per cent in 1997 (also see, Mathur and Sachdeva, 2005; and Singh, 2017).

Along with the lowering of tariff rates, there was a lowering of the effective rate of protection (ERP) of Indian manufacturing industries (accorded by tariff) during the 1990s.[16] It is important to recognize, however, that before the onset of tariff reforms in the post-1991 period, there was a good deal of 'water in tariff' (also called tariff redundancy). This arises when the tariff rate is more than the difference between the domestic price and the international price of a tariff-protected good. It means that the domestic producers are charging a price less than the maximum chargeable price level beyond which the price of the imported substitute (even after paying the tariff) will become cheaper – this is often caused by intense competition among the domestic producers in the local markets. To provide some data on this aspect in the Indian context, although the average tariff rate on industrial products was more than 100 per cent in 1986, the difference in the prices of like products in India and in international markets, which is known as implicit tariff, was on an average only about 50-60 per cent. For one sizeable section of industries, comprising mostly consumer goods industries, it was less than 30 per cent (Pursell *et al.*, 2007, pp. 5, 22-24). By 1991, going by the estimates made by Pursell *et al.* (2007:5), the average implicit rate of tariff was only about 30-40 per cent. Interestingly, it touched zero by 1993, increased slightly thereafter and then came back to zero by the end of the 1990s. An additional point to be noted here is that, in the early 1990s, tariff cuts were combined with substantial depreciation in the exchange rate that neutralized the effect of tariff cuts; this would be realized by examining the trends in the real effective exchange rate during the early 1990s (Goldar, 2002; Pursell, *et al.*, 2007). The main point being made here is that in the first half of the 1990s, the tariff cuts probably did not put a large section of the domestic manufacturers at any great disadvantage vis-à-vis imports because of (a) the previously prevailing significant 'water in tariff' (i.e., tariff redundancy) and (b) the fact that effect of tariff cuts was neutralized to some extent by exchange rate depreciation.

Given the changes that took place in respect of tariff rates on industrial goods and

15 See Goldar *et al.* (1992), Goldar and Saleem (1992), Nouroz (2001), and Goldar (2002) for information on tariff rates in the pre-reform period and in the initial five to ten years of the post-reform period.

16 For an analysis of trends in the effective rate of protection (ERP) of Indian manufacturing accorded by tariff in the 1980s, 1990s and 2000s, see Goldar and Saleem (1992), Nouroz (2001), Ahluwalia (2006), and Das (2003a, 2016). There is a clear indication that the ERP accorded by tariff to Indian manufacturing fell during the 1990s following the tariff cuts. According to the estimates presented in Ahluwalia (2006), the average ERP of Indian manufacturing fell from about 166 per cent in 1988-89 to 55 per cent in 1996-97. Das (2016, Figures 4.2 and 4.4) reports that the average ERP of manufacturing was 129 per cent in 1990-91, which fell to about 40 per cent by the end of 1990s, and to 21 per cent by 2009-10.

QRs, how does one interpret the findings regarding import penetration ratio – the absence of any marked increase in import penetration? Does this mean that the QRs on intermediate and capital goods were not constraining the imports of such goods before the QRs were removed? Or is it possible that although imports were permitted and tariffs were lowered, the exchange rate depreciation made imports very costly and therefore increases in imports did not take place? Or could this be interpreted as showing that the domestic industry was able to improve its competitiveness sufficiently after the initiation of trade reforms impelled by the challenges and strengthened by improved access to imported materials, parts and components, and capital goods, so that they could squarely meet import competition? If the last one is the true explanation or a major explanation, then a follow-up question that arises is, why did this improvement in the competitiveness of domestic producers not show up in the estimates of TFP growth in growth accounting studies? Taking a cue from this question and other observations made above, the basic purpose of the article, as stated earlier, is to draw attention to the possibility that the measured TFP growth for Indian manufacturing has not properly captured the improvements that took place. This is essentially the argument made.

Corrections Needed in TFP Growth Estimates

In this section, attention is drawn to three corrections that need to be made in computing TFP growth in Indian manufacturing based on the growth accounting methodology applied to ASI data for a valid comparison between the 1980s and 1990s. To provide empirical content to the arguments, a fresh set of TFP growth estimates are presented – these are shown with the corrections and without the corrections, so that the impact of corrections may be judged. The construction of the dataset on output and inputs is similar to (but not the same as) that in earlier studies of the present author (Goldar, 2015, and Goldar, 2017) and is explained in the online Appendix. [17] The basis data source is ASI, which is the source used by most earlier studies on TFP growth in Indian manufacturing.

Before taking up the corrections needed, it is important to provide some information on the gap in TFP growth rates between the pre-reform period and post-reform period (or to be more specific the initial phase of the post-reform period) reported in various studies. Table 1 shows the total factor productivity (TFP) growth estimates for Indian manufacturing (organized segment) covering most of the studies undertaken.

For the estimates based on the value-added function, the gap in TFP growth between the pre-reform and post-reform period is about one percentage point per annum or higher (with one exception where the gap is 0.5 percentage points). In some studies, the gap is about two percentage points per annum. In the case of the TFP estimates based on gross output function,

17 http://www.csls.ca/ipm/43/IPM_43_Goldar_Appendix.pdf.

Table 1: Estimates of TFP Growth in Indian Manufacturing, Earlier Studies

Author(s)	Pre-reform Estimated TFPG (% per annum) and period in parentheses	Post-reform Estimated TFPG (% per annum) and period in parentheses
Panel A: Based on Value-Added Function		
Trivedi *et al.* (2000)	3.06 (1981-82 to 1990-91)	1.96 (1990-91 to 1997-98)
Goldar and Kumari (2003)	4.27 (1981-82 to 1990-91)	1.60 (1990-91 to 1997-98)
Goldar (2004)	2.14 (1979-80 to 1990-91)	1.57 (1991-92 to 1999-2000)
Goldar (2006)	4.52 (1981-82 to 1990-91)	1.86 (1990-91 to 1997-98)
Ahluwalia (2006)	3.8 (1980-81 to 1990-91)	-7.8 (1991-92) 3.4 (1991-92 to 1997-98)
Rajesh Raj and Mahapatra (2009)	1.40 (1980-81 to 1990-91)	(-)0.52 (1991-92 to 2002-03)
Trivedi *et al.* (2011)	2.1 (1980-81 to 1990-91)	1.0 (1991-92 to 2007-08)
Datta (2014)	2.05 (1980-81 to 1990-91)	(-)0.45 (1990-91 to 2003-04)
Rijesh (2019)	3.4 (1980-81 to 1990-91)	2.9§ (1991-92 to 2007-08) (-)3.2 (2008-09 to 2013-14)
Panel B: Based on Gross Output Function		
Trivedi et al. (2000)	1.26 (1981-82 to 1990-91)	0.63 (1990-91 to 1997-98);
Goldar and Kumari (2003)	1.89 (1981-82 to 1990-91)	0.69 (1990-91 to 1997-98)
Trivedi (2004)	1.90* (1980-81 to 1991-92)	0.70* (1992-93 to 2000-01)
Goldar (2006)	2.13 (1981-82 to 1990-91)	0.90 (1990-91 to 1997-98)
Banga and Goldar (2007)Ä	0.88 (1980-81 to 1989-90)	0.26 (1989-90 to 1999-2000)
Virmani and Hashim (2011)Ä	0.61 (1981-82 to 1990-91)	0.25 (1990-91 to 1997-98)
Das and Kalita (2011)	0.65# (1980-81 to 1989-90)	0.31# (1990-91 to 1999-2000)

Major economic reforms began in India in 1991. The estimates of TFP growth for the post-reform period shown in the table include, in most cases, one or two years of the pre-reform era. However, it is appropriate to consider the estimates shown in the last column of the table as the estimates of TFPG for the post-reform period, since post-reform years dominate. (2) Most available studies on TFPG in Indian manufacturing at the aggregate level based on growth accounting are included in the table, but not all. (3) While specifying the period for which TFP growth estimates are provided, some authors have included the first year, and some have not. The periodization as given by the author(s) has been adopted for the table without making any change. (4) If both single-deflated and double-deflated GVA (gross value added) based estimates are available, the former has been taken.

This estimate of Das and Kalita (2011) is the average of ten two-digit industry-level estimates each of which is the Domar aggregation of TFP growth in constituent three-digit industries (together accounting for about 70 percent of manufacturing GVA). Das (2003b) presented estimates of TFP growth in three broad industry groups. For capital goods industries and consumer goods industries, the average rate of TFP growth during the 1990s was found to be lower than that during the 1980s. * Trend growth rates in TFP. § Combining the estimates for 1991-92 to 2000-01 and 2001-02 to 2007-08 provided in the study. *Ä* These studies use capital, labour, energy, materials, and services (KLEMS) as five inputs.

Source: Prepared by the author

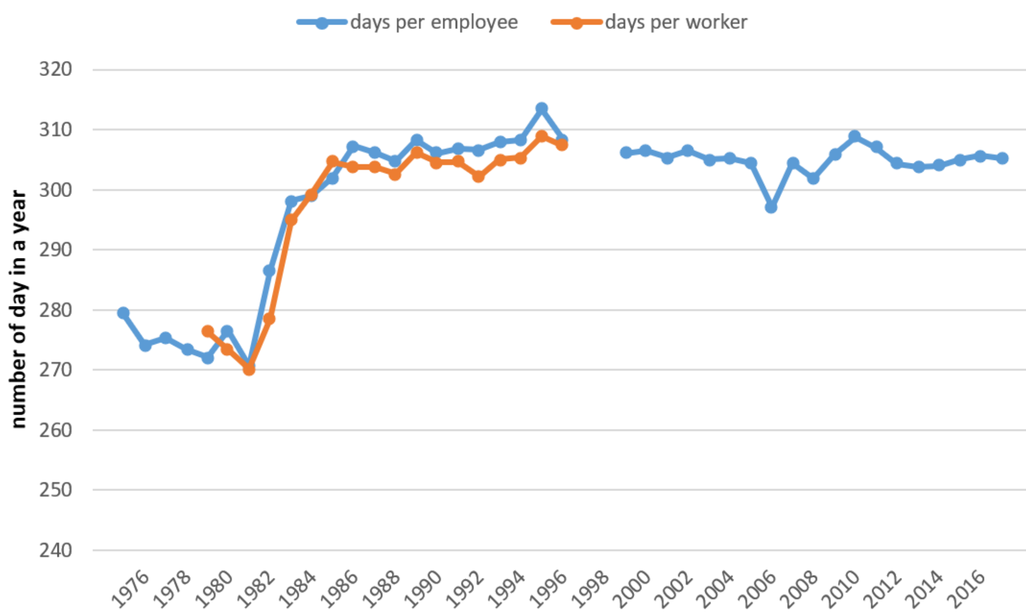
the gap is relatively smaller. But the gap in TFP rate between the post-reform period and the pre-reform period is more than one percentage point in some cases.

The shortcoming or inaccuracies in the computed TFP growth rates are taken up next. These points are relevant to the studies which are based on ASI data (applicable to most studies on TFP growth in Indian manufacturing).

Inaccuracy 1

One aspect to which attention needs to be drawn is that there was a significant increase in hours of work among workers in manufacturing in the 1980s, and this needs to be accounted for in the TFP growth estimates. This may be seen in Chart 1 which shows days worked per employee and days worked per worker during 1975-76 to 2017-18. During the 1980s there was a significant increase in days worked per employee and per worker, coming to an additional 35 days in a year. Going by headcount (number of persons employed or number of employees), the growth in labour input in manufacturing was slow in the 1980s, only 0.5 per cent per year. It is necessary to correct this by incorporating changes in days worked per

Chart 1: Days worked Per Year Per Worker and Per Employee, Indian Manufacturing, 1975-1976 to 2017-2018



Source and note: Author's computations based on EPWRF (Economic and Political Weekly Research Foundation) dataset which has been prepared using ASI data (hereafter called EPWRF dataset based on ASI). Data on days worked are not available for 1997-98 and 1998-1999.

employee. The average annual growth rate in days worked per employee was about one per cent during 1980-1990. This raises the growth rate in labour input in manufacturing during 1980-1990 from 0.5 to 1.5 per cent per annum.

In her analysis of jobless growth in Indian manufacturing in the 1980s, Bhalotra (1998a:23) has noted this phenomenon of significantly rising days worked per employee in that decade. She has provided some explanations for the observed hike in hours per employee in the 1980s: uncertainty, competition, fear,[18] and infrastructure development.[19] She has noted that the growth in hours worked per worker was one of the contributory factors to the measured TFP growth in Indian manufacturing in the 1980s.[20]

This raises a methodological question. If hours worked per worker go up in a particular period because of de-hoarding of surplus labour that existed at the beginning of the period, better infrastructure availability helping in cutting down power shortages and raw materials shortages, a changed policy environment, should this be treated as more labour input or as more productivity. Note here that in the empirical literature on productivity, labour input in manufacturing has been measured on the basis of hours worked in many studies rather

18 Falling employment and reduced support of government for workers induced fear and discipline among workers. Less time was lost because of industrial disputes.

19 Time losses on account of power shortages and materials shortfalls were avoided.

20 Bhalotra (1998b) observes that unless the recuperation of time losses are accounted for, the TFP estimates exaggerate TFP growth in Indian manufacturing in the 1980s.

than the number of persons (Kathuria *et al.* 2014:33).[21]

If one is undertaking a study on TFP growth in Indian manufacturing in the 1980s only, one may use the number of persons employed as the measure of labour input or base the measure of labour input on total days worked by all employees, and then interpret the estimates of TFP growth accordingly. But, when the estimates of TFP growth are to be compared between the 1980s and 1990s, and in one decade, days worked per employee has increased significantly and in the other decade there has been no such increase, then it seems reasonable to argue that it is essential to take into account the increases in days per employee in the 1980s as a part of increases in labour input to make the comparison meaningful. The implication is that the computed TFP growth for the 1980s will go down if this aspect is incorporated into the computation.

Inaccuracy 2

The second issue that needs attention relates to the income share of labour in gross value added. In applying the growth accounting methodology, it is assumed that factor income shares are equal to the elasticities of output with respect to the factors of production. This involves the assumptions of constant returns to scale and perfect competition in product and factor markets. Let α and β be the true elasticity of output (real gross value added) with respect to labour and capital. The rate of TFP growth (TFPG) is computed as:

$$TFPG = \hat{Y} - \alpha\hat{L} - \beta\hat{K} \qquad (1)$$

where the caret symbol denotes the growth rate, Y denotes real GVA (gross value added), L denotes labour input and K denotes capital input. Note, however, that the true elasticities are not known and in their place, the income shares are used. Let α^* be the observed income share of labour and β^* be the observed income share of capital.

The computed TFPG, denoted by TFPG′, then becomes:

$$TFPG' = \hat{Y} - \alpha^*\hat{L} - \beta^*\hat{K} \qquad (2)$$

If the observed income shares of labour and capital (α^* and β^*) deviate from the true elasticities (β and β), the measured TFP growth will differ from true TFP growth (see Box 1 in this context). The important question here is whether trade reforms had an impact on the labour income share and hence on the deviation of observed income shares from the true elasticities and did this cause an underestimation of TFP growth for the 1990s? It looks like there are reasons to believe so.

Protection from international trade results in rents which are distributed between labour and capital according to their rel-

21 This is not true for studies on India's organized manufacturing. The measure of labour input is based on headcount (e.g., total number of persons engaged) in Goldar and Kumari (2003), Unel (2003), Das (2003b), Goldar (2004b, 2006), Banga and Goldar (2007) Trevedi, *et al.* (2011), and Rijesh (2019). This is possibly true for several other such studies on manufacturing sector productivity based on ASI data.

ative bargaining power. There need not be proportional distribution of rents, proportional to non-rent factor incomes; hence α^* and β^* are expected to differ from the true elasticities. There is some literature for India and other developing countries which provides an empirical basis to argue that the removal of trade protection tends to lower the income share of labour.[22] This occurs presumably because relatively greater downward adjustments in their incomes are made by labour than capital as rents associated with protection are eroded with liberalized trade.

The average income share of labour in India's organized manufacturing (emoluments divided by GVA, both at current prices) was about 39 per cent during 1980-1990 and about 28 per cent during 1991-1999. One possible interpretation of these figures is that the labour income share in the post-reform period understates the true elasticity of GVA with respect to labour (hereafter called GVA-labour elasticity) in this period. Or one may argue that labour income share understates the elasticity in both pre-reform and post-reform periods, and the extent of deviation is greater in the post-reform period. If this is true,[23] then the conventionally measured TFP will understate TFP growth in Indian manufacturing, particularly in the 1990s.

The underestimation of TFP growth occurs because the growth rate in labour input in Indian manufacturing has been much lower than that in capital stock (which is taken as a measure of capital input). Hence, if the income share of labour is less than the GVA-labour elasticity because of the disproportionate redistribution of rents associated with trade reform, then this tends to raise the estimated growth rate in total input, and thus understates the growth rate in TFP. Possibly such a gap was there in the data for the post-reform period, causing an under-estimation of TFP growth. Or the gap might have been there in both pre- and post-reform periods but was greater in the post-reform period leading basically to the same or similar consequence.

To pursue the above line of argument further, let us consider the trends in labour income share and what adjustment is needed for a more accurate TFP growth measurement. A precise adjustment of the labour income share to reflect properly the GVA-labour elasticity is difficult to do, and thus not attempted here. Nonetheless, a rough adjustment is done based on two econometric exercises – in one exercise, a Cobb-Douglas two-input production function is estimated to derive the GVA-labour elasticity, and in the other exercise, an econometric model for explaining labour income share is estimated.

22 On this issue, especially in the Indian context, see Goldar and Agarwal (2005); Abraham and Sasikumar (2017); Gupta and Helble (2018); and Goldar (2022); among others.

23 Whether this is true or not, needs a detailed investigation. While some analysis is presented here, a complete, thorough treatment of issue is beyond the scope of the article.

Box 1: Factor Income Share and Output Elasticities

In applying the growth accounting methodology for estimating TFP growth, there is an assumption that factor income shares are equal to the elasticity of output with respect to various factors of production. In the case of a two-input production function, taking value added as output, and labour and capital as inputs, the application of growth accounting methodology assumes that the elasticity of real value added with respect to labour is equal to the income share of labour in gross value added, and the elasticity of real value added with respect to capital is equal to the income share of capital in value added. Since the income shares of labour and capital add up to one, there is an assumption of constant returns to scale. Doubts have often been expressed on the validity of these assumptions in the context of the application of the growth accounting methodology to industries in developing countries.

Unel (2003) presented estimates of TFP growth in Indian manufacturing in the pre- and post-reform periods. For one set of estimates, the elasticity of GVA with respect to labour was taken as constant at 0.6. The argument given is that labour income share in Indian manufacturing significantly understates elasticity of output with respect to labour, especially for the 1990s. He referred to the elasticities emerging from production function estimates in Ahluwalia (1991) and noted that labour's income share in manufacturing in five leading industrialized countries was in the range of 0.57 to 0.65. This issue has been examined in Goldar (2004).

In the analysis undertaken by Viramani and Hashim (2009) using an estimated CSE (constant elasticity of substitution) production function, they have found that wage rate and marginal productivity of labour in Indian manufacturing were nearly the same during 1980-91, but the wage rate was about 20 per cent lower than marginal productivity during 1992-2001. This means that labour income share was smaller than corresponding elasticity in the post-reform period. This finding has relevance to the analysis presented in this article.

Bosworth *et al.* (2007) have studied the sources of growth of the Indian economy using the growth accounting framework. Instead of using the income shares of labour and capital as elasticities for computing TFP growth for industry and services sectors, they take the output elasticity with respect to labour and capital as 0.6 and 0.4 respectively. They note that self-employed workers form a dominant part of employment in India, and there is considerable difficulty in separating labour income component and capital income component out of the mixed income of the self-employed. While there are some arguments for taking the GVA elasticity with respect to labour to be more than labour income share, a different set of arguments, for instance increasing returns to scale, embodied technological progress and externalities associated with investment, could provide a basis for taking the GVA elasticity with respect to capital as substantially above the income share of capital (Romer, 1987).

Table 2: Estimates of a Cobb-Douglas Production Function, Indian Manufacturing

Dependent variable: ln(Y/L)

Period: 1980-81 to 2017-18
(22 two-digit industries)

Explanatory variables	**Regression-1 (Fixed-effects)**	**Regression-2 (FGLS)**	**Regression-3 (difference GMM)**	**Regression-4 (system GMM)**
ln(Y/L)t-1			0.727(15.5)***	0.702(19.1)***
ln(K/L)	0.436(1.72)*	0.429(15.02)***	0.255(3.64)***	0.250(3.47)***
ln(K/L)*D1990-1999	0.030(0.72)	-0.031(-1.84)*	-0.075(-2.24)**	-0.066(-1.75)*
ln(K/L)*D2000-2007	0.166 (2.74)**	0.036(1.87)*	-0.021 (-0.62)	-0.009(-0.22)
ln(K/L)*D2008-2017	0.180(2.01)**	0.050 (2.66)***	-0.030(-0.65)	-0.016(-0.29)
D1990-1999	-0.107(-0.73)	0.116(1.74)*	0.229(1.97)**	0.187(1.44)
D2000-2007	-0.732(-3.04)***	-0.244(-2.79)***	-0.033(-0.28)	-0.082(-0.60)
D2008-2017	-0.868(-2.47)**	-0.374(-4.01)***	-0.022(-0.12)	-0.076(-0.35)
ln(man-days per employee)	0.055(0.19)	0.272(4.85)***	0.333(1.43)	0.425(1.80)*
Time (year)	0.032(2.94)***	0.037(17.69)***	0.006(1.71)*	0.007(3.05)***
Number of observations	836	836	792	814
R-squared	0.77			
F-value and prob.	73.8 (0.000)			
Wald chi-sqr and prob.		3810.0(0.000)	2795.5(0.000)	5921.0 (0.000)
Sargan test of over-identified restrictions, chi-sqr, and prob.			511.4 (0.92)	609.7(0.32)
AR(1)			-3.56(0.000)	-3.56(0.000)
AR(2)			2.15(0.031)	2.12(0.034)
No. of instruments			569	605

Source and note: Author's computation based on EPWRF dataset on ASI. In addition, data on prices have been used. Y=real gross value added; L=labour input (persons employed); K=deflated fixed capital stock. D1990-1999, D2000-2007 and D2008-2017 are dummy variable for the periods 1990-99, 2000-07 and 2008-17 respectively. Robust standard errors. t-values in parentheses. *, **, *** Statistically significant at 10 percent level, 5 percent level and one percent level respectively.

The estimation of a constant-returns-to-scale Cobb-Douglas two-input production function has been done by using panel data for 22 two-digit industries from the years 1980 to 2017. The fact that days per employee grew significantly during the 1980s has been incorporated into the analysis by taking days per employee as an additional explanatory variable.[24] A time trend variable is included to capture the impact of technical change as well as other developments in the economy. Intercept and slope dummy variables have been included in the estimated model for the periods, 1990-1999, 2000-2007, and 2008-2017. The purpose is to find out if the capital and labour elasticities in the periods 1990-99, 2000-2007 and 2008-17 were significantly different from that during 1980-89. The results are shown in Table 2. In regressions (1) and (2), the results obtained by applying the fixed-effects model and the feasible generalized least-squares (FGLS) method are presented.[25] In regressions (3) and (4), the

24 Number of persons employed and days per employee are taken as two variables instead of combining them into one variable to impart greater flexibility in modelling.

25 Tests of cross-sectional independence (Pesaran test, Friedman test, and Frees test) indicate the presence of cross-sectional dependence. This provides justification for using the FGLS method. In estimating the model, heteroskedastic and correlated error structure has been incorporated along with AR1 autocorrelation structure.

results obtained by applying the difference and system GMM (Generalized Method of Moments) estimators are presented.[26]

To take up the results in Regressions (1) and (2) first, the coefficient of the capital-labour ratio is found to be positive (as expected) and statistically significant. The numerical value of the coefficient is plausible as the elasticity of value-added with respect to capital input. The coefficient of the interaction term involving the capital-labour ratio and the dummy variables for the periods 2000-2007 and 2008-2017 are positive and statistically significant which indicates that the elasticity of real GVA with respect to capital was relatively higher (and thus the elasticity with respect to labour was relatively lower) in the periods 2000-2007 and 2008-2017 than that during 1980-1989. The interaction term involving the capital-labour ratio and the dummy variable for the period 1990-1999 is negative and statistically significant in the FGLS estimates. The hypothesis that the elasticity was the same between the two periods 1980-89 and 1990-99 is therefore rejected. This suggests that the GVA-labour elasticity during 1990-1999 was higher than that during 1980-1989 (contrary to the pattern seen in the actual income shares).

Turning next to the results in Regression (3) and (4), the coefficient of capital-labour ratio is found to be positive and statistically significant, as in Regressions (1) and (2). The interaction terms involving the capital-labour ratio and the period dummy variables for 2000-2007 and 2008-2017 are statistically insignificant. It may thus be inferred that the GVA-labour elasticities in 2000-2007 and 2008-2017 were not significantly different from that in 1980-1989. On the other hand, the interaction term involving the capital-labour ratio and the period dummy variable for 1990-1999 is negative and statistically significant, as in the FGLS estimates. This indicates that the elasticity of value added with respect to capital (hereafter GVA-capital elasticity) was lower and hence the GVA-labour elasticity was higher in 1990-1999 than that in 1980-1989. This is the opposite of what one might think based on observed trends in labour income share.

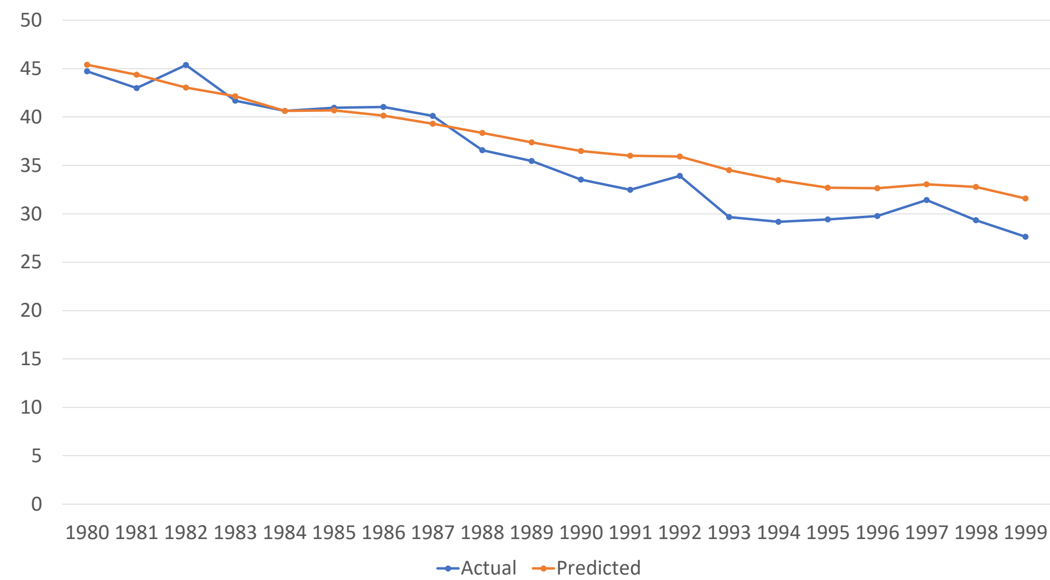
The results in Table 2 suggest that to apply the growth accounting methodology to compute TFP growth in Indian manufacturing in the post-reform period, the income share of labour for the 1990s should be adjusted upwards to the level of that in the 1980s, i.e., upward adjustment by about 11 percentage points or even higher.

In the second exercise, an analysis of inter-industry inter-temporal variation in labour income share is done by (a) estimating an econometric model to explain labour income share of various two-digit industries in the period 1980-1988, and then (b) using that model to predict labour income share for the 1990s which is then compared with actual labour income share.[27] The

26 The GMM and the FGLS methods have been used in the estimation of production based on industry-level data by Pablo-Romero *et al.* (2019).

27 Labour income share is regressed on the logarithm of capital-output (value added) ratio and time trend (see Annex-B). See Gupta and Helble (2018) who have employed a similar specification for a plant-level study with several other control variables added.

Chart 2: Labour Income Share in GVA (%), Indian Manufacturing, 1980-1999, actual and model predicted



Source and note: Author's computation based on EPWRF dataset on ASI. The estimated fixed-effects model that has been used for the prediction of labour income share (see Annex-B).

predicted (based on the fixed-effects model) and actual labour income for the period 1980 to 1999, the average across two-digit industries, are shown in Chart 2. A gap is found between the predicted labour income share and the actual labour income share for the 1990s. On this basis, it seems an upward correction of 3.3 percentage points in the average labour income share in the 1990s is needed to use the labour income share in the application of growth accounting.

Since the first exercise suggests an upward adjustment by 11 percentage points or higher and the second exercise suggests an upward adjustment by 3.3 percentage points, the middle path has been taken and thus the average of the two figures has been adopted. Accordingly, an upward adjustment by 7 percentage points has been done with the hope that with this adjustment labour income share in the 1990s will better represent the GVA-labour elasticity.

As a follow-up to the discussions on methodology above, some estimates of TFP growth in Indian manufacturing (organized) based on ASI data are presented next. Table 3 shows the growth rates in real GVA, labour inputs (persons employed) and capital input (fixed capital stock formed by perpetual inventory method) and labour income share in GVA for the periods 1980-1990, 1990-1999 and 1991-1999. Since 1991 was a year of economic crisis, it is perhaps not fair to include it in the post-reform period to evaluate the relative performance in the two periods. Hence, for the post-reform period, growth rates in the years 1990-1999 and 1991-1999 are both considered, the latter being the preferred sub-period for judging the relative performance.

It is evident that based on the conventional measure of TFP, the performance in terms of TFP growth was relatively worse in the post-reform period (see the second

Table 3: Growth Rates in Real GVA, Labour and Capital Input, and TFP, Indian Manufacturing

Period	Real GVA (% p.a.)	Labour (% p.a.)	Capital (% p.a.)	Labour income share	TFP (% p.a.)	TFP alternate (% p.a.)
1980-1990	8.1	0.46	7.18	0.39	3.5	3.4
1990-1999	7.28	1.25	8.72	0.28	0.7	1.1
1991-1999	8.85	1.3	9.05	0.28	1.9	2.5

Source and note: Author's computation based on EPWRF dataset on ASI (along with data on prices).

last column) – a gap of about three percentage points per annum. The gap reduces substantially when the period 1991-1999 is taken rather than 1990-1999, which seems to be more appropriate for comparison to evaluate the impact of reforms. In this case, the gap is 1.6 percentage points per annum.

The revised set of estimates of TFP growth that are obtained after incorporating the above-mentioned two adjustments relating to days per employee and labour income share is presented in the last column of Table 3. The gap in the growth rate of TFP between the pre- and post-reform periods comes down substantially. In this case, the gap is 0.9 percentage points per annum.

Inaccuracy 3

Attention may next be drawn to another possible source of bias in TFP estimates. This bias arises from differences in the growth rate of prices of energy input and that of manufactured products.

Energy prices grew faster than manufacturing sector output prices in the 1970s. The gap considerably narrowed in the 1980s when the growth rate in energy prices was only slightly higher than the growth rate in prices of manufactured products (6.6 as against 6.1 per cent per annum).[28] In the 1990s, again, energy prices grew faster than manufactured product prices – the trend growth rate during 1990-99 were 9.7 per cent per annum for fuel, power, light and lubricants and 6.7 per cent per annum for manufactured products. The implication is that if the single-deflated value added is used for computing TFP growth (as in Table 3), there will be a downward bias in the estimated TFP growth for the post-reform period of the 1990s.[29]

To address this issue regarding the divergence between the rate of growth in energy prices and that in manufactured product prices which tends to create a bias in the estimates of TFP growth based on the single-deflated GVA, a KLE (capital-labour-energy) production function is used. In this framework, the net output is defined

28 These comparisons are based on the official series on wholesale price indices, Office of the Economic Adviser, Department for Promotion of Industry and Internal Trade, Ministry of Commerce and Industry, Government of India

29 For a discussion on the biases in TFP measurement arising from the use of single-deflated GVA, see Balakrishnan and Pushpangadan (1994 and 1998); and Rao (1996).

30 Energy cost is deflated by an energy price index to derive the series on energy input. For a discussion on econometric estimation of the KLE production function, see Brockway *et al.* (2017), among others.

Table 4: Growth Rates in Real Net Output, Labour and Capital Input, Energy Input, and TFP, Indian manufacturing (KLE production function framework)

Period	Real net output (GVA+ energy cost) (% p.a.)	Labour (% p.a.)	Capital (% p.a.)	Energy (% p.a.)	Labour income share in net output	Energy income share in net output	TFP (% p.a.)	TFP alternate (% p.a.)
1980-1990	8.2	0.46	7.18	5.52	0.3	0.24	3.32	3.02
1990-1999	7.27	1.25	8.72	3.84	0.22	0.23	1.31	1.72
1991-1999	8.55	1.3	9.05	3.77	0.21	0.23	2.38	2.8

Source and note: Author's computation based on EPWRF dataset on ASI.

as gross output minus materials and services input. There are three inputs: labour, capital and energy.[30] The growth rate of TFP is obtained as the growth rate in deflated net output minus the growth rates in labour, capital and energy inputs weighted by their respective income shares. The computed growth rates of TFP for the pre-reform and post-reform periods obtained by applying the KLE production function framework are shown in Table 4.

After energy input is incorporated into the method of computing TFP growth based on growth accounting, the rate of TFP growth for the period 1991-1999 is found to be only one percentage point lower than the growth rate in TFP for the period 1980-1990 (see second last column). In the next step, adjustments are made for the increase in days per employee in the 1980s and the dip in the income share of labour in the 1990s because of which a gap probably arose (or the existing gap got widened) between labour income share and the GVA-labour elasticity. After making these adjustments, the growth rate in TFP in manufacturing during 1980-1990 is found to be 3.0 per cent per annum and that during 1991-1999 is found to be 2.8 per cent per annum – the gap is only 0.2 percentage points.

One point that may be raised here is concerned with the computation of capital stock series, for which the rate of economic depreciation has been taken as 5 per cent. However, in the initial period after the onset of trade and other economic reforms, the rate of obsolescence of capital assets must have been relatively higher and there is justification for using a higher rate of depreciation for the first half of the 1990s. If a higher rate of deprecation is applied say 6 or 7 per cent per year, the annual average growth rate in capital stock in the 1990s will go down, and the gap in the growth rate in TFP between the 1980s and 1990s seen in Table 4 will probably disappear. The growth rate in TFP in the 1990s may even turn out to be higher than that in the 1980s if a higher rate of deprecation is applied to the 1990s on the ground that the rate of obsolescence of capital assets was much higher in the 1990s than in the 1980s.

Since the estimates of production function presented in Table 2 have played a key role in the adjustments made above, a brief discussion on the reliability of the production function approach to deriving the GVA-labour elasticity rather than base it on income share would be in order here.

It is known that due to market imperfections in emerging economies, the key assumption in the growth accounting framework that factors are paid according to marginal product is not valid and there is some advantage in carrying out productivity analysis based on an estimation of a production function. The advantage of the production function approach is that the assumption of constant returns to scale and perfect competition need not be imposed (Kathuria, *et al.*, 2014:43). The major disadvantage of the production function approach is the problem of identification of the production function because of simultaneity in the determination of inputs and output. Additionally, there are problems of autocorrelation and multi-collinearity, and biases in estimates caused by errors in the measurement of inputs, particularly capital input.

Because of the errors in the measurement of capital input, the coefficient of capital tends to be underestimated and if one imposes constant returns to scale, the coefficient of labour is over-estimated. Thus, the production function approach does not necessarily have a clear advantage over the growth accounting approach. Also, when one uses time-series data on aggregate manufacturing or industry-wise panel data for estimating a production function, one is assuming implicitly that an aggregate production function exists. The existence of an aggregate production function requires several stringent conditions including the condition that each specific type of labour and capital should receive the same price in each industry (Jorgenson *et al.* 2005:364). Thus, the competitive market assumption probably becomes necessary to ensure that the same price prevails in each industry for a specific type of labour or capital.

While the above point about the aggregation applies to the production function estimates based on industry-level data, the production function estimates based on plant-level data used in the analysis presented later in Section 4 do not involve an aggregation to the economy level. In these estimates, the GVA-labour elasticity is found to be above 0.5, supporting the estimates based on the industry-wise panel data in Table 2. A very similar estimate of the elasticity of real GVA with respect to labour (0.54 to 0.59) is reported in Gupta and Veermani (2015a, Table 4) based on plant-level data of ASI.

To sum up, in the discussion above, certain corrections that need to be made to TFP growth estimates for the 1980s and 1990s for ensuring a valid comparison were pointed out and a fresh set of estimates of TFP growth in Indian manufacturing with and without making the corrections were presented. The upshot of the above discussion is that if due corrections are made to TFP growth estimates, there is a very small difference (or no difference at all) in the estimated growth rates of TFP in Indian manufacturing between the decade preceding the economic reform and the initial phase of post-reforms. Next, the analysis is taken a step further. A theoretical analysis concerning productivity growth is presented on the basis of which a bias in TFP measurement for Indian manufacturing in the post-reform period is identified.

Providing Empirical Content to the Estimation Bias Identified

There is an extensive literature on how market imperfections can result in a downward bias in TFP measurement. The online Appendix argues that due to trade reforms a downward bias might arise in the estimates of TFP growth in Indian manufacturing in the 1990s because in this period the rent element in GVA existing earlier was significantly eroded.[31] The analysis presented in the appendix is rather simplistic as it did not taken into account the developments in the exchange rate and the relative prices between tradeable goods and non-tradeable goods and services because of the trade reforms. A full theoretical analysis has not been done here. This will be taken up in future research.

In this section, the issue is addressed empirically. To assess the impact of trade liberalization on rents, a production function is estimated in which the effective rate of protection (ERP) is introduced as an additional variable. A simple Cobb-Douglas specification is used. Real GVA is taken as output and the number of persons employed and fixed capital stock at constant prices are taken as labour and capital input. It should be noted that these data enter in the computation of TFP indices. The issue raised is, if there is an element of rent within the real GVA and it is affected by changes in ERP, then the computation of TFP will also be affected. This is subjected to empirical verification by investigating whether the element of rent in GVA is impacted by changes in ERP.

The production function (representing technology) used for empirical analysis based on panel data on industries (subscript i) over time (subscript t) may be written as:

$$Y_{it} = A_{it} L_{it}^{\alpha} K_{it}^{\beta} \tag{3}$$

In this equation, Y denotes gross value added (real), L labour input and K capital input. The term A represents total factor productivity. GVA is the observed gross value added which has two components: the true value addition denoted by Y and the rent component proportion denoted by R such that GVA=Y(1+R). There are a set of factors (w) which influence variations in A across industries and over time. There is another set of factors (z), probably overlapping with w to some extent, which influences the rent component. The estimable equation may thus be derived as:

$$GVA_{it} = A\,(w)_{it}[1 + R(z)_{it}] L_{it}^{\alpha} K_{it}^{\beta} \tag{4}$$

This equation is estimated in log-linear form. It is assumed that ERP influences both the 'A' component and the 'R' component of the above equation. The influence of w (which includes ERP) is assumed to be picked up by a variable B along with the industry dummies and time dummies. As regards z, ERP is taken as one of the variables impacting R. The estimable equation thus becomes (allowing for some approxi-

31 http://www.csls.ca/ipm/43/IPM_43_Goldar_Appendix.pdf.

mation):

$$lnGVA_{it} = a_i + b_t + \theta B_{it} + \phi ERP_{it} + \alpha lnL_{it} + \beta lnK_{it} + u_{it} \quad (5)$$

The above model is estimated by using panel data on industries for the years 1986 to 1999 with the additional assumption of constant returns to scale. Data on ERP at the two-digit industry level have been taken from Goldar and Kumari (2003, Appendix Table 1) for the years 1983-84, 1989-90, 1992-93, 1994-95 and 1997-98. Additionally, ERP for various industries for the years 1999-2000 has been taken from Virmani *et al.* (2004), which is then matched with the estimates for earlier years. Using this information and applying interpolation, a dataset on ERP has been formed for 12 industrial groups for the years 1986-87 to 1999-2000. Accordingly, the 22 industries mentioned earlier have been mapped into 12 industry groups. Data on real GVA, labour and capital input has been taken for the corresponding 12 groups for the same years.

There is difficulty in constructing an appropriate variable B that will pick up the influence of w on TFP. Unable to find a suitable method of handling the problem, the variable is proxied by the price-based measure of TFP. This is based on the price function which is dual to the production function. If $Y = f(L, K)$ is the production function, then there exists a price function $P_Y = g(P_L, P_K)$ as its dual where P_Y, P_L and P_K are the prices of output (value added), labour input and capital input. The Divisia price index of technical change or the rate of growth in TFP may be written as (Jorgenson and Griliches, 1967):

$$\widehat{A^p} = \alpha_L \widehat{P_L} + \alpha_K \widehat{P_K} - \widehat{P_Y} \quad (6)$$

In this equation, the caret symbol represents the growth rate. Aiyar and Dalgaard (2005) find that the estimates of TFP growth they obtain by using the price function are different from that obtained from the primal, i.e., the production function. Thus, there is some justification for using the price-function-based estimates of TFP growth for the aforementioned 12 industry groups as a proxy for the variable B in equation (13) for its estimation.

To implement this methodology, data on P_Y, P_L and P_K have been taken. P_Y is the deflator of GVA. P_L is computed as the ratio of total emoluments to the number of persons employed, and P_K is computed by subtracting total emoluments from the current price GVA and dividing the balance by the constant price fixed capital stock. Since the production function is assumed to be of the Cobb-Douglas form, this should also apply to the price function. Thus, $ln(P_Y)$ has been regressed on $ln(P_L)$ and $ln(P_K)$ to obtain the coefficients which are treated as approximating the parameters α_L and α_K in equation (6). This provides the growth rate in A^p, i.e., the price-based measure of TFP. Applying the growth rates, an index has been formed for each industry group, taking the first-year value as 1.0. Then, the logarithm of the index is used as a variable to represent B in equation (5).

The estimated regression equations are shown in Table 5. It is assumed the production function is characterized by con-

Table 5: Estimates of Production Function with ERP as Additional Variable, Indian Manufacturing

Dependent variable: ln(real GVA/L)

Period: 1986-87 to 1999-00 (12 industry groups) – 168 observations

Explanatory variables	Fixed-effects model	Random-effects model	Pooled mean group estimator	Dynamic fixed effects model
	Regression-1	Regression-2	Regression-3	Regression-4
ln (K/L)	0.406 (5.62)***	0.466 (5.22)***	0.326 (7.05)***	0.313 (3.35)***
ERP	0.0005 (-0.86)	0.0005 (-0.67)	0.0005 (1.67)*	0.0011 (2.13)**
Price-based TFP measure	1.4 (12.72)***	1.39 (10.18)***	1.065 (10.85)***	1.333 (9.56)***
Time			0.048 (10.85)***	0.056 (7.17)***
Error correction term			-0.702 (10.85)***	-0.644 (-8.48)***
R-squared	0.53	0.59		
Wald Chi-square and prob.	12062.7 (0.000)	6.005.7 (0.000)		

Source and notes: Author's computation based on EPWRF dataset on ASI along with data on ERP. Year dummies are included in Regression-1 and Regression-2. L=labour and K=capital. t-values in parentheses. *, **, *** statistically significant at 10, 5 and 1 percent respectively. For the fixed and random-effect models, the bootstrapped standard errors are used. For the pooled mean group estimator and dynamic fixed-effects model, the long-run coefficients are shown in the table.

stant returns to scale, and accordingly, the logarithm of the real GVA to labour ratio is regressed on the logarithm of the capital-labour ratio, with ERP and the price-based TFP index (B) as additional explanatory variables. In the model, the dummy variables for years have been used to pick up the influence of year-specific factors. To begin with, the equation is estimated by the fixed-effects model and the random-effects model, the results of which are shown under Regression-1 and Regression-2 in Table 5.

From the results presented in Regression-1 and Regression-2, it is found that the coefficient of log(K/L) is positive as expected. The coefficient is found to be statistically significant. What is important to note is the positive coefficient of the ERP variable. However, in the estimates obtained by the fixed- and random-effects model, the coefficient is statistically insignificant. Thus, there is some indication of a bias, but not a strong one.

To carry out a more sophisticated econometric analysis, panel unit-root tests of the four variables ln(GVA/L), ln(K/L), ERP and the estimated price-based TFP have been done. The tests indicate that ln(GVA/L) and ln(K/L) are integrated of order zero, i.e., these are I(0). For ERP, the test results are conflicting. It seems this variable could be I(0) or I(1). In the case of the price-based TFP, it is found to be I(1). Hence, the results presented under Regression-1 and Regression-2 come into question. In such a situation, a panel ARDL (auto-regressive distributed lag) model will be more appropriate. Accordingly, the pooled mean group (PMG) estimator and the dynamic fixed-effects (DFE) models have been applied. The results are shown under Regression-3 and Regression-4 in Table 5. In these two cases, instead of using time dummies, a time trend variable has been used.

In the estimates of the pooled mean group (PMG) model and the dynamic fixed-effects (DFE) model, the coefficient of capital intensity is found to be positive, but not statistically significant. Perhaps, the use of the trend term has caused this. However, the coefficient of ERP is found to be positive and statistically significant. This could be treated as econometric evidence of a bias in the measurement of real GVA growth caused by the lowering of ERP.

Given that effective protection has fallen about 60 percentage points between the end of 1980s and the end of 1990s,[32] and the fact that the TFP growth rate in the 1990s was almost as high as that in the 1980s (after making appropriate corrections, see the last column in Table 4), it would perhaps not be wrong to claim that the TFP growth performance in Indian manufacturing was better in the 1990s.

Plant-Level Analysis of the Impact of Trade Liberalization on TFP

Existing Literature for Indian Manufacturing

Several studies have been undertaken on the impact of trade liberalization on productivity in Indian manufacturing using firm-level or plant-level data. The findings of these studies indicate that trade liberalization had a positive effect on productivity in Indian manufacturing.[33]

Most of these studies are based on data on manufacturing companies drawn from the Prowess database of the Centre for Monitoring Indian Economy (CMIE). Some studies have used ASI unit-level data.[34] In most of these studies undertaken for Indian manufacturing, the Levinsohn-Pertin (2003) methodology for measuring TFP has been used. Kealey *et al.* (2019) has raised the question of whether the method applied for the estimation of TFP at the firm/plant level makes a difference to the results of the regression analysis carried out subsequently for assessing the impact of trade liberalization on productivity. They have taken data on Columbian manufacturing plants between the years 1981 to 1991 and compared the results of estimated econometric models linking trade policy to TFP based on three alternate methods of estimation of TFP: Levinsohn and Petrin (2003), Ackerberg *et al.* (2015), and Gandhi *et al.* (2017). They find that when the productivity estimates obtained by the Levinsohn and Petrin method are used, the regression results show a positive effect of trade liberalization on productivity, but not when they use the method suggested by Gandhi, Navarro, and Rivers (2017) for productivity estimation, which is based on a more flexible form of the production function. They conclude that the nature of the relationship between trade

32 The 60 percentage points decline in ERP when coupled with the estimated regression coefficient of the DFE model implies a fall in GVA (due to erosion of rent component) by about 6 per cent in 10 years. This would mean that the measured annual TFP growth rate in Indian manufacturing in the 1990s needs to be raised by 0.6 percentage point to make valid comparison with the measured TFP growth rate for the 1980s.

33 The studies include Krishna and Mitra (1998), Topalova and Khandelwal (2011), Ahsan (2013), Harrison *et al.* (2013), Gupta and Veeramani (2015a) and Goldar *et al.* (2020).

34 The studies undertaken by Harrison *et al.* (2013) and Gupta and Veeramani (2015a) are based on the unit-level data of ASI and thus have a much bigger coverage of the factories in the organized manufacturing sector. Natraj (2011) used unit-level ASI data as well as such data for the informal sector units.

policy and TFP found in the regression analysis is not robust to the method of productivity estimation.

A Fresh Analysis of the Effect of Trade Reforms on TFP based on Plant-level Data

Since bigger industrial enterprises have higher capabilities, they are in a better position to meet the challenges of trade liberalization and gain from it. Such gains may be smaller or even absent for small-sized industrial enterprises. The observed growth in TFP following trade reforms in the data for aggregate manufacturing will be subject to the extent of differences between big and small industrial enterprises in terms of the productivity-enhancing effects of trade reforms, and the relative share of these two categories of enterprises in the aggregate GVA. To examine this aspect, an analysis of the effect of the tariff on TFP in manufacturing plants has been undertaken using the unit-level data of ASI. The coverage extends to the entire organized manufacturing sector.

Another interesting issue is the role of 'water in tariff', as discussed in Section 2. In a regression analysis, taking productivity as the dependent variable and the effective tariff rate as the explanatory variable, the estimated coefficient is likely to be affected if there is considerable 'water in tariff'.[35] An attempt made to address this issue is shown in the Table in on-line Appendix.[36]

The dataset used for the analysis is the same as used in Goldar (2020). The period covered in the dataset is 1998-99 to 2012-13. However, the estimation of TFP and the regression analysis for assessing the impact of tariff rates on TFP have been done by using data for the years 1998-99 to 2010-11.

For measuring TFP, a two-input Cobb-Douglas production function is used. Deflated GVA is taken as the measure of output. The number of persons employed is taken as the measure of labour input. Deflated value of the fixed capital stock (net closing value) is taken as the measure of capital input. Deflated value of energy cost is taken as a proxy for capturing productivity shocks. Productivity estimation has been done for only those plants which were covered in the ASI survey at least three times during the years 1998-99 to 2012-13.

NRP, ERP and the rate of input tariff are the main explanatory variables. The data on NRP (tariff) and tariff-based ERP used for the analysis is for the years 1997-98 to 2009-10.[37] Since the tariff and ERP variables are used in the econometric model with a one year lag, the productivity and other related data are taken for the years

35 This does not affect the studies that use the relative price, domesetic versus international (refecting implicit tariff) as the explanatory variable. See Chand and Sen (2002) and Rijesh (2019).

36 http://www.csls.ca/ipm/43/IPM_43_Goldar_Appendix.pdf.

37 The author is grateful to the recently deceased Professor Deb Kusum Das for kindly sharing the database on NRP and ERP he had constructed at three-digit industry level which was utilised by him for the report he prepared for the Reserve Bank of India (Das, 2016). These data were used in Goldar *et al.* (2020). Using these data on NRP along with tariff data on agricultural and mineral products, the author has constructed the input tariff rates.

1998-99 to 2010-11. For combining the data on NRP (output tariff), ERP and input tariff with the productivity estimates a mapping of industrial classifications has been done. For each plant, the industrial class (at a four-digit level of National Industrial Classification, 2004) to which it belonged during 2004-05 to 2007-08 has been considered.

Estimation of TFP at the plant level has been done by using three methods: Levinshon and Petrin (2003), Ackerberg *et al.* (2015), and Wooldridge (2009). Separate regression equations have been estimated for the plants having a fixed capital stock of Rs 20 million or more (at 2011-12 prices) and the plants with smaller capital stock.

For model estimation, the logarithm of TFP is taken as the dependent variable and the one-period lagged value of NRP, ERP or input tariff rate is taken as the explanatory variable along with year dummies. In addition, two other variables are introduced in the equation. These are the share of contract workers in total workers employed and the share of ICT (information and communication technology) assets in total fixed assets.

A panel dataset on plants is used for the regression analysis. Data on about 50,000 plants are used. The number of observations per plant is about five on average. The estimation method for the regressions is the fixed-effects model. The standard errors have been clustered at the plant level. The results are shown in Table 6.

The results indicate a positive effect of trade liberalization on TFP in Indian manufacturing plants. Interestingly, when data on all plants are taken, NRP and ERP have a significant positive coefficient for the productivity estimates based on the Levinsohn-Petrin (2003) method, not for productivity estimates based on the Ackerberg-Caves-Frazer (2015) method and the Wooldridge (2009) method. When the analysis is undertaken separately for the factories with a fixed capital stock of Rs 20 million or higher and the factories with smaller capital stock, the results for the three sets of productivity estimates are found to be similar. A positive effect of tariff reform on TFP is found for the relatively bigger plant with a capital stock of Rs 20 million or more. The effect is minimal or absent among small-sized plants (similar finding has been reported by Mukerjee and Chanda, 2020). ASI data for 2011-12 reveals that the plants with a fixed capital stock of Rs 20 million or more accounted for about a quarter of the total number of operating factories, more than 90 per cent of aggregate value-added, more than 95 per cent of aggregate fixed capital stock and about 70 per cent of aggregate employment of organized manufacturing. Thus, the trend in productivity at the aggregate level of the manufacturing sector should reflect mostly the impact of trade reforms on the relatively bigger plants.

The favourable impact of input tariff cuts on TFP is found to be bigger than the impact of output tariff cuts. This finding is consistent with the findings of several earlier studies including Schor (2004) for Brazil, Amiti and Konnings (2007) for Indonesia and Topalova and Khandelwal (2011) and Gupta and Veeramani (2015a) for India.

As regards the role of 'water in tariff' or tariff redundancy, the results in online Appendix C suggest that in industries in

Table 6: Impact of Trade Policy on TFP, Plant-level Analysis, 1998-2010

Explanatory variable	All Plants		Plants with Real Fixed Capital Stock of Rs 20 million or more		Plants with Real Fixed Capital Stock below Rs 20 million	
Panel-A: TFP estimated by the Levinsohn-Petrin (2003) method						
Lagged NRP	-0.0005		-0.0011		0.0003	
	(-1.66)*		(-2.53)**		-0.61	
Lagged input tariff	-0.0021		-0.0052		-0.0008	
	(-5.05)***		(-7.37)***		(-1.44)	
Lagged ERP		-0.0003		-0.0008		0.0002
		(-1.84)*		(-2.81)***		-0.67
CW	-0.077	-0.076	-0.152	-0.145	-0.046	-0.046
	(-8.02)***	(-7.89)***	(-9.59)***	(-9.18)***	(-3.92)***	(-3.91)***
ICT	1.656	1.643	1.578	1.552	1.587	1.584
	(13.53)***	(13.42)***	(6.38)***	(6.25)***	(10.92)***	(10.90)***
F-value and prob.	128.8	133.6	72.2	72.7	55	58.1
	0	0	0	0	0	0
Panel-B: TFP estimated by the Ackerberg-Caves-Frazer (2015) method						
Lagged NRP	-0.0004		-0.0008		0.0002	
	(-1.35)		(-1.86)*		-0.39	
Lagged input tariff	-0.0013		-0.0038		-0.0003	
	(-2.94)***		(-5.39)***		(-0.50)	
Lagged ERP		-0.0002		-0.0005		0.0002
		(-1.04)		(-1.84)*		-0.68
CW	-0.114	-0.113	-0.191	-0.186	-0.065	-0.065
	(-11.85)***	(-11.76)***	(-12.06)***	(-11.77)***	(-5.36)***	(-5.35)***
ICT	3.033	3.024	2.817	2.798	2.577	2.575
	(23.31)***	(23.25)***	(11.05)***	(10.95)***	(16.80)***	(16.79)***
F-value and prob.	98	103.1	53	54.3	50.8	54
	0	0	0	0	0	0
Panel-C: TFP estimated by the Wooldridge (2009) method						
Lagged NRP	-0.0005		-0.001		0.0003	
	(-1.51)		(-2.39)**		-0.63	
Lagged input tariff	-0.0021		-0.0051		-0.0007	
	(-4.88)***		(-7.22)***		(-1.32)	
Lagged ERP		-0.0003		-0.0007		0.0002
		(-1.64)		(-2.68)***		-0.78
CW	-0.101	-0.1	-0.181	-0.174	-0.067	-0.067
	(-10.53)***	(-10.40)***	(-11.35)***	(-10.95)***	(-5.66)***	(-5.65)***
ICT	1.545	1.532	1.465	1.44	1.495	1.492
	(12.64)***	(12.53)***	(5.92)***	(5.79)***	(10.31)***	(10.29)***
F-value and prob.	128.7	133.9	70.9	71.6	57.3	60.5
	0	0	0	0	0	0
No. of obs.	236,524	236,524	97,041	97,041	139,483	139,483

Note: Year dummies are included. CW= share of contract workers in total workers. ICT= share of ICT assets in total assets. T-values in parentheses. *, **, *** statistically significant at 10, 5 and 1 percent respectively. Source: Author's computations from unit-level data of ASI.

which there is substantial 'water in tariff', cuts in output tariff do not have a significant impact on the TFP of manufacturing plants.[38]

Conclusion

There is a substantial body of literature on the impact of trade liberalization on productivity in manufacturing in emerging economies based on firm-level or plant-level studies including such studies for Indian manufacturing. Sufficient econometric evidence has been presented in these studies to establish that the liberalization of trade enhances the productivity of the manu-

38 http://www.csls.ca/ipm/43/IPM_43_Goldar_Appendix.pdf.

facturing sector. However, several studies on TFP growth in Indian manufacturing based on the growth accounting methodology have reported a lower estimate of the growth rate in TFP in the period after India initiated major trade reforms (in 1991) along with other complementary economic reforms than that in the earlier period. Accordingly, there is a view that TFP growth in Indian manufacturing in the 1990s following the major industrial and trade reforms undertaken in India was lower than that in the decade preceding the reforms. This article has questioned that view. Certain corrections that need to be made in the computed TFP growth rates for the 1980s and 1990s were pointed out. Also, it was argued that in a period of rapid trade reforms as was the situation faced by Indian manufacturing in the 1990s, a downward bias in TFP growth estimates may arise. Based on the estimates presented, the rate of TFP growth in Indian manufacturing was higher in the 1990s than in the 1980s.

To look into the differential impact of trade reform on big and small industrial enterprises, an analysis of the impact of trade reforms on TFP in Indian manufacturing was undertaken using plant-level data for the years 1998 to 2010. This research revealed that while the relatively bigger manufacturing plants in India with a fixed capital stock of Rs 20 million and above gained in productivity from trade liberalization, their small-sized counterparts, three times in number, did not have such gains. Also, an attempt was made to incorporate the issue of 'water in tariff' explicitly into the econometric analysis of the effect of change in nominal tariff on manufacturing plants' productivity. The results of this analysis suggest that the presence of 'water in tariff' makes a difference in the regression results obtained.

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