On-line Appendix

Appendix 1: Market Imperfections and Biases in TFP Measurement

Some Existing Studies

There is extensive literature on how markups and unionization of labour result in a bias in TFP measurement - a difference arising between the Solow residual, i.e., the measured TFP growth and the true rate of technical change or TFP growth. Some of the studies have examined this issue in the context of trade reforms. The sub-section presents a very brief discussion of a few of the existing studies that have dealt with the divergence between the Solow residual and the true TFP growth in a situation characterized by markups and unionization, and then the implication of the findings of these studies for the analysis presented above is pointed out. It is useful to begin the discussion with the basic equation defining the TFP growth (equal to Solow residual under certain assumptions) which is similar to eq. (1), but is based on a three-input production function:

$$\hat{A} = \hat{Q} - \alpha\hat{L} - \beta\hat{K} - \gamma\hat{M} \qquad (1)$$

In this equation, Q, M, L and K are real output, real intermediate input, labour input and capital input, respectively. The caret symbol is for growth. The parameters α, β and γ are the true factor elasticities, and thus $\hat{A}$ denotes the true growth rate in the level of TFP. Due to markups and unionization or other such market imperfections, the equation is transformed to:

$$\hat{S} = \hat{Q} - \alpha'\hat{L} - \beta'\hat{K} - \gamma'\hat{M} \qquad (2)$$

In this equation, $\hat{S}$ is the Solow residual. The difference between equations (1) and (2), i.e. between $\hat{S}$ and $\hat{A}$ is the bias.

Dobbelaere (2005) shows that the Solow residual can be decomposed into four elements, which relate to (i) markup, (ii) a scale factor (representing returns to scale), (iii) trade union bargaining power and (iv) the rate of technical change or true TFP growth, $\hat{A}$. From the equation derived, it is seen that the impact of an increase in the markup on the bias depends on the gap between the growth rates in output and capital stock.

Harrison (1994) analyses the impact of markups on the measurement of TFP growth and shows that the nature of bias in the measurement of TFP depends on the direction of growth in L/K and M/K. If the growth rates in L/K and M/K are negative or their weighted average is negative (which will describe the situation prevailing in Indian manufacturing in the 1980s and 1990s), then markups will make $\hat{S}$ less than $\hat{A}$ in the pre-reform period, and thus a lowering of markups to zero caused by trade reforms will make $\hat{S}$ in the post-reform period equal to $\hat{A}$, thereby exaggerating the productivity gain associate with the reform.

Crouzet and Eberly (2021) argue that the mismeasurement of intangible capital and rising markups have caused a downward bias in the measurement of TFP growth in the US in the recent period. In the equation derived by them for the bias in the measured TFP growth based on a value-added function, the bias depends on the GVA-labour elasticity, the level of markup, and the difference between the growth rates in capital and labour. They observe that because of the markups, the true GVA-labour elasticity is higher than the measured labour income share, which causes a downward bias in TFP measurement, if capital is growing faster than labour.

Maiti (2013, 2019) has used a value-added function framework and derived an equation linking the Solow residual to the true TFP growth in the presence of markups, union power and non-constant returns to scale. This is similar to the equation in Dobbelaere (2005). Applying this equation econometrically to Indian manufacturing with the help of ASI data for 1998-2005, Maiti (2013) finds that the conventional measure yields a TFP growth rate in Indian manufacturing of about 1 per cent per annum, but after corrections, this is found to be only a half of that.

Going by the findings of the econometric studies undertaken on Indian manufacturing in respect of the impact of trade reforms on the level of markups and the bargaining power of labour, one may surmise that trade liberalization led to a decline in markups (see, for example, Gupta and Veeramani, 2015b; and Goldar and Agarwal, 2005) and in the bargaining power of labour (see, for example, Ahsan and Mitra, 2014; and Pal and Rathore, 2014). It may be argued accordingly that the fall in markups caused an exaggeration in TFP growth in the estimate made for the 1990s (following Harrison, 1994) and therefore the measured TFP growth for the 1990s needs to be adjusted downward to make a proper comparison with the estimate the 1980s. This will nullify the entire chain of arguments made in Section 3 above to establish that the rate of TFP growth in the post-reform period was not lower than that in the pre-reform period. As a counter to this, it should be noted that the fall in the bargaining power of labour had a counterbalancing effect, perhaps exceeding the effect of the fall in the markup rates, with the net result that it is the TFP growth rate estimated for the 1980s that need to be adjusted downward to make a proper comparison with the estimates for the 1990s.

In the next sub-section, a somewhat related issue is taken up for analysis which is strictly not connected with the discussion in this sub-section but falls under the ambit of biases in TFP growth measurement. The analysis is not based on a contrast between equations (7) and (8). Rather, this may be viewed as the bias in the measurement of real GVA growth that arises in the path of transition as an economy moves from the situation described by equation (8) to the situation described by equation (7).

Bias in Measured TFP Growth Arising from GVA Growth Mismeasurement

Consider the following simplified framework that is set out to show how trade intervention impacts <u>measured</u> TFP growth through the measurement of real GVA growth.

Let Q be output, and P_Q be the price of output. Let M_1, M_2 and M_3 be three different intermediate inputs (which could be generalized to three categories of inputs). M_1 is traded (for example, steel sheets), M_2 is imported, but is a non-competing import and its price is administered (for example, crude oil) and M_3 denotes non-traded goods/services used as intermediate inputs in the manufacturing sector. PM_1, PM_2 and PM_3 are the corresponding prices.

Let L denote labour input (e.g., number of persons employed) and K denote capital input. K is made up of past investments. Suppose Is is the real value of investment done in year s and δ is the rate of depreciation (say 5 per cent), then K_t, the capital stock in year t, may be written as

$$K_t = \int_{-\infty}^{t} I_s(1-\delta)^{t-s} \tag{3}$$

Let the elasticity of output (i.e., real value added) with respect to labour be a fixed number and the elasticity with respect to capital be β (assuming a Cobb-Douglas production (value added) function). It is assumed further that $\alpha+\beta=1$, i.e., production technology is characterized by constant returns to scale and the product and factor markets are perfectly competitive.[1]

The TFP index may be written as (the numerator is gross value added, and the denominator is a measure of total input):

$$TFP = \frac{P_Q Q - [M_1 PM_1 + M_2 PM_2 + M_3 PM_3]}{L^{\alpha} K^{\beta}} \tag{4}$$

$$TFP = P_{\frac{GVA}{L^{\alpha}K^{\beta}}} \tag{5}$$

The growth rate in TFP is:

$$\widehat{TFP} = \widehat{GVA} - \alpha\hat{L} - \beta\hat{K} \tag{6}$$

The caret symbol denotes the growth rate. Since α and β are not known, these will be represented measured by observed income shares of labour and capital in gross value added under the assumption of constant returns to scale and competitive markets.

This is the *measured* TFP growth when there is no trade intervention and the value of output, intermediate inputs, annual investments and fixed capital stock are at domestic prices which are the same as international prices. Also, when there are no distortions in labour and capital input markets, α and β will be equal to factor shares.

Let us consider next how interventions in the trade regime through the imposition of tariffs and QRs impact the above measure of TFP. In the presence of distortions due to trade barriers and imperfections in factor markets, the measured TFP growth would differ from the 'true' TFP growth.

1 This assumption is perhaps not necessary for the main points put forward in this section but is being made for simplicity of exposition.

The measured TFP level may be written as:

$$TFP' = \frac{P'_Q Q - [M_1 PM'_1 + M_2 PM'_2 + M_3 PM'_3]}{L^{\alpha *} K'^{\beta *}} \quad (7)$$

P' and PM'_1, PM'_2 and PM'_3 are prices actually prevailing, which are different from those in international markets. $P'Q$ and PM'_1 are postulated to be higher than the corresponding prices in international markets (because of tariffs and QRs). Although M_3 is non-traded, it will be using traded inputs in production and the enhanced prices of traded goods used in the production of M_3 is likely to cause its price to be higher than what it would have been in the absence of trade protection.

In the next step, let us consider the definition of effective rate of protection (ERP). ERP for a production activity (or an industry) is defined as value added at domestic prices divide by value added at international prices (or, it may be expressed as domestic value added divided by international value added). In terms of the expressions in the equations used in the discussion of the framework above, ERP may be written as:

$$ERP = \frac{P\prime_Q Q - [M_1 PM\prime_1 + M_2 PM\prime_2 + M_3 PM\prime_3]}{P_Q Q - [M_1 PM_1 + M_2 PM_2 + M_3 PM_3]}$$

$$= \frac{GVA_D}{GVA_I} \quad (8)$$

In a situation where trade reforms are bringing down the effective rate of protection of domestic industries (it has been noted above that the ERP of Indian manufacturing accorded by tariff came down substantially in the post-reform period, see footnote 16), the numerator will be reduced and move closer to the denominator. Since TFP measurement is based on the numerator (see equation 7), the downward pressure on domestic gross value added might create a downward bias in the estimates of TFP growth in the post-reform period.[2]

It should be realized that even if no substantive changes take place in the production activity in terms of the quantum of products produced, the quantum of materials, energy, etc. used and the number of workers and the plant and machinery remain the same, the lowering of tariff will cause the domestic value added to go down. Essentially, in the process of tariff reform, the rent element is eroded. The decline in value-added caused by erosion of rent is obviously not a decline in TFP. If the measure of TFP must capture prop-

2 This assertion involves a number of assumptions. In reality, the situation could be different. First, the tariff cuts would often be accompanied by exchange rate deprecation. This will raise the sales realization of exporting firms. Second, more firms may be encouraged or facilitated (because of better access to imported inputs) to enter export markets. This will result in productivity gains through the export-related learning. It is obvious that the analysis here is based on several simplifying assumptions. However, the author is hopeful that the main point made in this section regarding bias in TFP measurement will come through even if a more general framework is used for the theoretical analysis.

erly the efficiency with which production activity is turning inputs into output, the inter-temporal change in the rent element should be properly accounted for because it will otherwise introduce a bias in the measurement of TFP.

Box A: How a fall in ERP may coincide with a fall in real GVA: An Illustration

According to India's input-output table for 1993-94, total output of manufacturing was Rs 4889 billion, and gross value added was Rs 1248 billion. The intermediate input used (inter-industry flows) within the manufacturing sector was Rs 1577 billion. Inputs from agriculture and mining were Rs 437 and Rs 297 billion (total Rs 734 billion) and other inputs including electricity, construction and services (treated as non-tradeable) were Rs 1330 billion. The import weighted average tariff rates on the final products produced by the manufacturing sector in 1993-94 was on average about 53 per cent (based on tariff rates for consumer goods and capital goods), and that on manufactured intermediate goods was about 48 per cent (rates taken from Mathur and Sachdeva, 2005, Table 1B), which is treated as the rate applicable to the manufactured interemediate goods consumed by the manufacturing sector. The import weighted average tariff rates for products of agriculture and mining were about 20 per cent and 33 per cent respectively. In this situation, if the tariff rates for manufactured products are lowered by 10 percentage points, the price of consumer and capital goods will fall on average by about 6.5 per cent, and that in manufactured intermediate goods will fall by 6.8 per cent (assuming domestic price = internaitional price plus tariff). Since the tariff levels of agricultural goods and minerals do not go down, their prices will remain by and large the same. The same applies to other inputs such as services. These costs will therefore not change or change marginally. The gross value added will come down to Rs 1035 billion, i.e., a 17 per cent decline. If value added is deflated by the output price index (applying single-deflation), the deflated value added shows a fall even though no pertinent change has taken place in the production process measured in terms of volumes on input used and output produced. Prior to the change in tariff the ERP was 64 per cent (based on the simple Corden method); it declines to 51 per cent after the reduction in tariff rates.

The reason for the decline in real GVA along with a fall in ERP occurring in the above example is that (a) there is an escalated tariff structure – higher tariff at higher level of processing to encourage domestic manufacturing industry and (b) tariff reduction is accomplished by a gradual compression of top tariff rates – the peak rate is lowered in stages (Panagariya, 2004; Singh, 2017).

The fall in real GVA will not occur if the manufacturing enterprises are able to pass on the entire loss of revenue to other sectors of the economy, say the services sector. For this, the supply curve of the services sector should be inelastic. This does not seem realistic. Rather, the supply curve of the services sector is likely to be elastic. If the manufacturing firms are able to cut down their intermediate input requirements substantially post the tariff reduction, then the real GVA need not fall. It may remain at the same level. However, this means that the measured TFP growth is not picking up this improvement in efficiency, because the measured growth in real GVA is nil.

An alternate way of viewing equation (8) is to treat the denominator as the efficient processing margin in a particular product line. This is so because this is the processing margin prevailing in the international markets presumably reflecting the processing margin of efficient producers. With the imposition of high tariffs on imports, the ERP goes up and the numerator goes up. Thus, the processing margin in the country (India) becomes higher than that prevailing internationally. This is obviously not a sign of greater productivity. Now, as tariff rates come down and ERP falls, the numerator will come down to the level of the denominator. This means that the processing margin in the country will match that of the efficient international players. This should obviously not be treated as a decline in productivity. It is doubtful if the methods of measurement of output, inputs and TFP as it is practised now would be able to separate the "true" value-added change and the change in the rent element in value added (see Box A). If this cannot be done, then a downward bias in TFP measurement for the post-reform period may arise. It appears therefore that the conventional measure of TFP using the deflated value of gross value added may not be giving the correct signals about productivity growth when large reductions are made in tariff rates and non-tariff barriers in a short period. Indeed, there is a possibility that the TFP growth rate will be underestimated.[3]

Appendix 2: Data Source and Measurement of Real Value-Added, Labour Input, Capital Input and Labour Income Share

Data Source

The basic source of data for the analysis is the dataset prepared by the Economic and Political Weekly Research Foundation (EPWRF) by compiling the ASI (*Annual Survey of Industries*) data. The dataset at the two-digit industry level has been used; the period covered is 1973-74 to 2017-18. The data have been provided in the EPWRF dataset according to the two-digit industries of National Industrial Classification (NIC), 2004. The industries NIC-15 to NIC-36 have been combined to obtain the estimates for the manufacturing sector. It should be noted that ASI data relate to the organized segment of Indian manufac-

3 Ahluwalia (2006) estimated the rate of TFP growth in the Indian manufacturing at 3.8 per cent per annum during 1980-1990 and 3.4 per cent per annum during 1991-1997. In evaluating the performance, she pointed out that a limitation of the TFP measure is that it is based on the growth in value added at domestic prices and does not consider the changes in the domestic prices relative to that in international prices. She noted further that in the 1990s, the domestic prices of industrial products in India had moved much closer to the international prices with the lowering levels of protection. Accordingly, she concluded that the estimates of TFP growth for the 1990s reflect the productivity gains much better than that for the 1980s. This is in spirit what is being argued here.

turing.

Variables

Gross value added (GVA): Data on gross value added at current prices for different two-digit industries are taken from the EPWRF dataset. There are deflated by price indices for the respective two-digit industries. The price indices are with base 2004-05=100. The deflators have been formed by using the wholesale price indices (Office of the Economic Advisor, Department for Promotion of Industry and Internal Trade, Ministry of Commerce and Industry, Government of India). The indices with bases 1970-71, 1981-82, 1993-94, 2004-05 and 2011-12 have been combined (spliced) to construct price indices for different two-digit industries for the years 1980-81 to 2017-18. For each two-digit industry, a suitable price index or deflator has been formed from the item-wise and group-wise wholesale price indices from the official series. In some cases, the price index for the two-digit industry could be found in the official WPI series directly. In other cases, these were derived from item-wise wholesale price indices by taking a weighted average (weights taken from the official WPI data). After obtaining the price series, the base has been shifted to 2004-05. Having obtained real value added for each two-digit industry, these have been added to derive real value added for aggregate (organized) manufacturing.

Net output (NQ): Net output is formed by adding the cost of fuels consumed to the gross value added. This has been deflated to derive the net output at constant prices. The deflators used are the same as those used for deflating GVA. The real net output series has been formed for each industry, and then added to derive the series for the manufacturing sector.

Labour input (L): Total number of persons engaged has been used as the measure of labour input. It includes all employees and also includes working proprietors, and their family members who are actively engaged in the work of the factory even without any pay (see Annual Survey of Industry writeup for 2017-18, http://www.csoisw.gov.in/CMS/UploadedFiles/ASIWrite_Up_2017_2018.pdf). For some analyses, the changes in man-day worked per employee have been taken into account.

Labour and capital income share (SL and KL): Labour income share in GVA is obtained by dividing total emoluments by gross value added, both at current prices. Capital income share is obtained as one minus labour income share. When the KLE production function framework is used, labour income share is obtained as total emolument divided by net output (= Gross value added + fuels consumed). In this case, capital income share is obtained as one minus the labour income share and the share of energy cost in net output.

Energy input (E): Date on fuels consumed has been taken for each industry and then these have been added to derive the series for aggregate manufacturing. The series on fuel consumed has been deflated by preparing a suitable price index for energy consumption in manufacturing. For this purpose, wholesale price indices for coal, electricity and petroleum products have been taken. Also, a price series (with some interpolation) has been formed for natural gas. For the recent period, 2004-05 onward, data on the price of natural gas has been obtained from *Indian Petroleum and Natural Gas Statistics* (Ministry of Petroleum and Natural Gas, Government of India). It is difficult to get the price of natural gas from earlier years. Information for certain years in the past has been taken from the Report of the Committee on Natural Gas Pricing (Chairman: T. L. Sankar), December 1996. In addition, from the plant-level data of ASI, the average price paid for gas has been computed for the years 1999 to 2004 which has been used for interpolation. For getting the price index of energy for the manufacturing sector, the price indices of coal, electricity, petroleum products and natural gas have been combined using weights. Three sets of weights have been used for different periods. These have been taken from the input-output tables for 1993-94, 1998-99 and 2007-08. The price index formed in this manner has been converted to base 2004-05=100.

Capital stock (input) (K): Capital input is measured by the fixed capital stock. The concept used is the net fixed asset (net of depreciation). The series on the capital stock has been formed for each two-digit industry and then added to derive the series for aggregate manufacturing. For deflation, the implicit deflator of gross fixed capital formation (GFCF) in manufacturing has been derived from data on GFCF at current and constant prices available in *National Accounts Statistics* (NAS). The 2011-12 base series of NAS and its corresponding back series have been used.

The construction of fixed capital stock series involves three steps: (a) construction of benchmark estimate of fixed capital stock, (b) construction of series on real gross fixed investment, and (c) construction of fixed capital series with the help of the benchmark estimate and the gross fixed investment series. These are further explained below:

(a) Benchmark estimate. The benchmark capital stock estimate has been made for 1973-74. For this purpose, data on the net and gross fixed assets by three-digit industries for the census sector of ASI and the sample sector of ASI for the years 1964-65 and 1968-89 have been taken. A mapping of the three-digit industries as per the classification prevailing in 1964-65 and 1968-69 with the two-digit industries of the EPWRF data set has been done. Accordingly, gross investment in each two-digit industry has been computed for the years 1965-66 to 1968-69 and 1969-79 to 1973-74. The net fixed capital stock figure for 1964-65 has been multiplied by a factor of 2 to obtain an approximation to the replacement value of the fixed capital stock in that year (which has then been inflated to express it at 2004-05 prices). The gross investments during the periods 1965-66 to 1968-69 and 1969-70 to 1973-74 (with proper deflation) have then been added to the estimated fixed capital stock of 1964-65 (allowing for 5 percent deprecation every year) to obtain the estimate of fixed capital stock for 1973-74 at 2004-05 prices which is the benchmark estimate of capital stock series.

(b) Gross investment in each industry i in each year t is computed for the years 1974-75 to 2017-18. The following equation

Appendix Table 1: Impact of NRP on TFP, Regression Results, By Estimation Method and the Level of Implicit Tariff Rate in the Pre-Reform Period

Explanatory variables	TFP estimates based on Levinsohn-Pertin (2003) method		TFP estimates based on Ackerberg-Caves-Frazer (2015) method		TFP estimates based on Wooldridge (2009) method	
	Low implicit tariff in 1986	Medium and high implicit tariff in 1986	Low implicit tariff in 1986	Medium and high implicit tariff in 1986	Low implicit tariff in 1986	Medium and high implicit tariff in 1986
NRP (effective tariff rate) (t-1)	0.00004 -0.11	-0.0016 (-2.18)**	0.00038 -1.16	-0.0018 (-2.39)**	0.00009 -0.27	-0.0016 (-2.12)**
Contract worker intensity	-0.074 (-5.29)***	-0.084 (-6.22)***	-0.086 (-6.11)***	-0.143 (-10.56)***	-0.096 (-6.80)***	-0.112 (-8.25)***
ICT intensity	1.806 (7.33)***	1.643 (11.07)***	3.439 (12.87)***	2.914 (18.55)***	1.686 (6.84)***	1.533 (10.36)***
F-value and prob.	41 0	108.1 0	32.9 0	80.6 0	41.7 0	107.4 0
No. of obs.	97,855	127,683	97,855	127,683	97,855	127,683

Source: Author's computations.

Notes: (1) Pursell *et al.* (2007) have provided, for various three-digit industries, the level of implicit tariff prevailing in 1986-87. Three levels are indicated: low (below 30 percent), medium (30 percent and higher, but below 70 percent) and high (70 percent or more). The extent of 'water in tariff' was relatively high among industries put in the "low" implicit tariff rate group. This group mostly includes the manufacture of food products, beverages, tobacco products, textiles, leather and leather products and non-metallic mineral products. It contains most of the consumer goods industries. The extent of tariff redundancy was relatively low among industries grouped under "medium" and "high". By the end of the 1990s, the average effective tariff rate was reduced to about 30 percent. The average implicit tariff rate fell to almost zero (thanks mainly to the exchange rate depreciation) and thus some level of 'water in tariff' continued – probably more for the industries grouped under "low" than for the industries grouped under "medium" and "high". If there is a good deal of 'water in tariff', cuts in the effective tariff rates are unlikely to impact firms belonging to that industry. The empirical results bear this out. (2) The total number of observations used in this analysis is less by about 10,000 than that in Table 7 because for some industries, the level of implicit tariff is not provided in Pursell *et al.* (2007) **, *** Statistically significant at 5 percent level and one percent level respectively.

is used:

$$I_{it} = B_{it} - B_{i,t-1} + D_{it} \qquad (9)$$

In this equation, B_t is the book value of fixed assets in year t, B_{t-1} is that in the previous year, and D_t is the depreciation (accounting depreciation, annual) of fixed assets in that year. It denotes gross investment in year t. This has been deflated by the price index mentioned earlier to obtain real gross investment. One difficulty that was encountered in applying the above procedure is that the gross investment turned out to be negative for a portion of industry-year observations. In those cases, the investment has been taken as zero, and the negative amount has been adjusted to adjacent years (commonly the next year).

(c) Having obtained the benchmark fixed capital stock for 1973-74 (year ending), and the annual gross investment in each industry, the series on fixed capital stock is formed by the perpetual inventory method: $K_t = 0.95 * K_{t-1} + [I_t/P_t]$ where K denotes fixed capital stock and P is the deflator mentioned earlier. The rate of economic depreciation has been taken as 5 percent.