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Discussion Paper Series No. 13

ENDOGENEITY OFTHE SOLOW RESIDUAL: Some Evidence From Indian Data

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Abstract

There are at least two reasons why the debate regarding the impact of openness or liberalization on productivity growth is unresolved. First, there is no adequate theory of TFP growth and second, the empirical measurement of TFP is fraught with difficulties. An important methodological issue that has attracted limited attention in India is regarding the assumptions that are necessary for implementing the traditional growth accounting approach. The assumptions of constant returns to scale, perfect competition and full capacity utilization must hold if unbiased estimated are to be obtained. Ideally the growth accounting technique should yield an estimate of TFPG that is exogenous to the rate of growth of output. Any departure from these assumptions and/or an error in the measurement of inputs or outputs leads to a pro-cyclical bias in the measurement of the Solow residual. The presence of such a pro-cyclical relationship between productivity and output often leads observers to erroneously conclude that there is a causal relationship between the two variables.

In this paper we present four examples from Indian data that help to illustrate the issues involved. We conclude that, if the existence of market power or non-constant returns to scale is not accounted for, the Solow residual has a pro-cyclical bias. Second, both the single deflation method and the double deflation method yield estimates of the total factor productivity residual that are pro-cyclical. Third, adjustment of the capital stock for capacity utilization rates reduces the extent of the pro-cyclical bias but does not eliminate it. And finally, correcting for market power reduces the extent of the bias.

JEL Classification : D24 O47

Keywords: **Total factor productivity, Solow residual, estimation bias, India.**

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June 2000

Published by
P.K. Krishnaswamy, Registrar & Secretary
National Council of Applied Economic Research
Parisila Bhawan, 11 - Indraprastha Estate
New Delhi - 110 002

Printed at
Vandana Print &Co.
1885, Sui Walan, Darya Ganj, New Delhi - 110 002.
Tel.: 3262747

CONTENTS

1. INTRODUCTION

Ever since the seminal paper by Solow (1957), a substantial literature has been generated on total factor productivity growth (TFPG). Although a part of the literature focuses on the problems associated with the measurement and estimation of TFPG and related issues, much of this literature focuses on factors such as the policy environment that could lead to higher TFPG rates. There are those who argue that liberalization and greater openness lead to improvements in TFPG rates. Others point to the absence of a theoretical relationship between liberalization and TFPG. Although this has important policy implications, the debate is unresolved. The available within-country evidence and cross-country evidence is both mixed and inconclusive.[1] Justifiably, this has not reduced interest in the subject. Long-term improvements in living standards are only possible if there is a sustained increase in productivity. More reliable and robust empirical work is required to for identifying the channels through which changes in the policy environment could lead to improvements in TFP growth.

There are at least two reasons why it is difficult to arrive at any definitive conclusions about the impact of policy on TFP growth. The first of these is that there is no adequate theory of TFPG. For example, Prescott (1997) finds that differences in physical and intangible capital cannot account for the large differences in income that characterize the world economy and that savings rate differences are of minor importance. Cross-country case studies of industry lead him to conclude that the ability of labor to resist the adoption of new technologies can explain some of the observed productivity differences and this, in turn, depends on the policy environment. It follows that TFP is important and that a theory of TFP must account for differences in TFP that arise for reasons other than the growth in the stock of technical knowledge. Balakrishnan and Pushpangadan (1998) argue that the attempt to relate TFPG to the policy regime is an "atheoretical" approach. Srivastava (1999) summarizes some of the prevalent arguments relating liberalization and growth but concludes that theory does not provide an unambiguous answer regarding the relationship between liberalization and TFP growth.

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[1] This is part of the general literature on openness and growth. As this literature is well known and there are several excellent reviews available, we will not review it here. See Tybout (1991) for a survey of the theoretical literature and the empirical evidence. Pack (1988) and Havyrlyshyn (1990) provide other surveys of the empirical evidence. For recent developments in the debate see the papers by Anne Krueger, JA Ocampo and Lance Taylor and D. Greenaway, W. Morgan and P. Wright in the section entitled "Controversy: Trade Liberalization and Growth" in The Economic Journal, Vol. 108, No. 450, September 1998.

Second, an empirical resolution of the problem is complicated by the fact that data for the estimation of TFP growth are generally not available in the form required by the theoretical models. For every variable there are different possible ways of adapting the available data to the requirements of the theoretical model. Each of these is susceptible to criticism. Measurement errors in the original data further complicate the problem. In addition there is a choice between using the traditional growth accounting (deterministic) approach and obtaining econometric (stochastic) estimates of TFPG. The existing, often conflicting, empirical evidence shows that the results are obviously sensitive to the choice of method, the data used and to the manner in which variables have been measured.[2]

One empirical issue that has attracted a great deal of attention in India is the choice between value added and gross output as the measure of output, and the related issues of single versus double deflation of value added and separability of the production function (see, for example, Balakrishnan and Pushpangadan 1994, 1995, 1996, 1998 and Rao 1996a and 1996b). This is an important issue and we hope that the extensive discussion on the subject that has already taken place will lead to improvements in the state of the art as far as empirical estimation of TFPG is concerned. A methodological issue that has attracted somewhat less attention is regarding the assumptions that are necessary for implementing the growth accounting approach to measuring TFPG. As is well known, the assumptions of constant returns to scale, perfect competition and full capacity utilization are necessary for obtaining unbiased estimates of TFPG using the growth accounting methodology. To the extent that these assumptions do not hold, the estimates will be biased. The problem is aggravated in a changing policy environment since the same factors that could lead to changes in TFPG could also change the degree of market power (price-cost margins) and the returns to scale parameter. Thus any before (reform) and after (reform) comparisons are further confounded by this fact.

In this paper we will focus on these sources of bias, and will present some examples which, in our view, suggest that the assumptions probably do not hold in the Indian case, and that traditional estimates of TFPG are, therefore, typically pro-cyclically biased. On the other hand, evidence presented in Paquet and Robidoux (1997) suggests that both US and Canadian manufacturing industry are characterized by constant returns to scale and perfect competition and that the Solow residual is exogenous after accounting for capacity utilization. In a study

[2] A major reason why the debate regarding the relationship between liberalization and (productivity) growth is unresolved is the considerable problems associated with the measurement of openness or liberalization. These are summarized in Edwards (1998) and Harrison and Hanson (1999) and we will not address these here.

of US manufacturing industries Ryan (1997) found that procyclicality persisted even after accounting for imperfect competition in the measurement of productivity. These results indicate that productivity as well as price cost margins tend to decrease more in a recession than increase during a boom. This is explained by labor hoarding or by assuming that a productivity shock is not Hicks neutral but is a negative shock to labor productivity.

The rest of this paper is organized as follows. In the next section we discuss briefly the state of the debate and the prevalent practice in recent TFPG studies in India. In section III we discuss the theory that explains the pro-cyclicality of the Solow residual and in section IV we present some empirical examples which suggest that the Solow residual is endogenous. Section V concludes with some suggestions for the direction of further research.

2. STATE OF THE ART, KNOWLEDGE AND PRACTICE[3]

Although there were a number of TFPG studies for India prior to these[4], the studies by Ahluwalia (1991) and Goldar (1986, 1990) were the first to attempt to systematically relate changes in TFP growth to changes in the policy environment. Ahluwalia's (1991) finding of a "turnaround" in TFP growth rates in the 1980s (attributed largely to economic reforms) attracted a great deal of attention. Balakrishnan and Pushpangadan (1994) rightly focused on the importance of correctly measuring TFPG. They drew attention to the considerations that were relevant for choosing between a gross output and a value added production function and to the issue of single versus double deflation of value added. They pointed out that deflating value added by a single deflator (as had been done by Ahluwalia and Goldar) was only valid if the price of material inputs did not change relative to the price of output - an assumption that was not likely to hold ordinarily. They went on to show that double deflation of value added reversed Ahluwalia's finding of a turnaround. Since then the matter has been extensively debated and discussed, with Rao (1996a and 1996b), Dholakia and Dholakia (1994, 1995) and Balakrishnan and Pushpangadan (1995, 1996) making important contributions. More recently, Pradhan and Barik (1998) reject the hypothesis of separability, implying that gross output rather than value added should be the preferred measure of output.

Where does this leave us? A more recent review of the state of the art and knowledge is provided by Balakrishnan and Pushpangadan (1998) and Pushpangadan (1999).

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[3] This phrase is adapted from Balakrishnan and Pushpangadan (1998). This is justified in view of their extensive contribution to the subject.

[4] Krishna (1987) provides a detailed survey of the literature up to that time.

Summarizing the existing estimates they find that the two approaches provide contradictory results. They conclude by noting that unless the superiority of one approach is clearly established, we will have to live without a definitive answer with respect to what actually happened to TFPG in India during the 1980s (and, for that matter, the 1990s). Thus, even though the state of the art appears to have improved considerably, the state of our knowledge remains quite poor.

Although our own bias is in favour of econometric estimates over non-parametric estimates of productivity growth, we will not enter into this debate here. We will, instead, focus on the growth accounting approach, the assumptions necessary for correctly estimating the Solow residual and the implications of the failure of these assumptions. Although most writers on the subject are aware of these issues, with a few notable exceptions[5], they have not attempted to correct for this[6]. We hope in this way to contribute to the state of the practice (the art, we believe, is well known) of growth accounting estimation of TFPG.

3. THE SOLOW RESIDUAL AND MACROECONOMIC FLUCTUATIONS : A REVIEW OF THE THEORY

Total factor productivity growth (TFPG) is typically measured by the difference in the rate of growth of output and a weighted index of input growth. That part of output growth that cannot be explained by the growth in inputs is attributed to productivity growth. In the two input case the Solow residual is given by:

$$\theta_t = \theta + u_t = \Delta q_t - \alpha_t \Delta l_t - (1-\alpha_t)\Delta k_t \quad .....(1)$$

where, Δq is rate of growth of output, Δl is the rate of growth of labor, Δk is the rate of growth of capital, α is the share of labor in total revenue, θ_t is the rate of Hicks neutral technical progress, and u_t is the stochastic element of technical progress.

Under perfect competition, α is an exact measure of the elasticity of output with respect to labor. Assuming constant returns to scale (CRS), the elasticity of output with respect to capital is $(1-\alpha)$. With these two assumptions and no other restrictions on the production function the relevant elasticities can be computed directly from data on compensation and revenue.

[5] Rao (1996b) is one.

[6] For example, most of the papers on the subject presented at the Workshop on Measurement of Productivity in India, organized by the Institute of Human Development in New Delhi on July 9-10, 1999, use traditional methods.

When the conditions of perfect competition and constant returns to scale hold then the Solow residual should be uncorrelated with any exogenous variable unconnected with true productivity changes. In other words, it should not be correlated to any factor or variable that leads to output or price changes and with business cycle changes. A major technological innovation is seldom immediately effective in causing a boom in production. It is also not reasonable to suppose that efficient technological processes are abandoned during a slump. This is what Hall (1986, 1988 and 1990) terms as the "invariance property" of the Solow residual. According to Hall (1990:74), "Under competition and constant returns to scale, the Solow residual is uncorrelated with all variables known to be neither causes of productivity shifts nor to be caused by productivity shifts". Thus, the empirically observed procyclical behaviour of the Solow residual can be explained by departures from the assumptions of perfect competition and constant returns to scale.

Absence of Perfect Competition and Constant Returns to Scale

In the presence of market power, marginal cost is substantially lower than price and revenue is always higher than costs because of the prevalence of monopoly profits. In such cases labor's share in revenue, used in the calculation of the Solow residual, understates the marginal contribution of labor to output. As a result, the Solow residual would tend to have an upward bias. Any increase in output due to an exogenous factor like an increase in labor supply would, therefore, lead to an erroneous measurement of the productivity residual. Accounting for the presence of market power but continuing with the assumption of constant returns to scale, the Solow residual is given by

$$\theta_t = \Delta q_t - \mu_t \alpha_t \Delta l_t - (1 - \mu_t \alpha_t)\Delta k_t \quad \ldots\ldots(2)$$

where μ (mark up) = price/marginal cost. Multiplying the labor share in revenue with the mark up converts labor's share in revenue to labor's share in costs. This cost based share ($\mu\alpha$) measures exactly the elasticity of output with respect to labor. With CRS, the elasticity of output with respect to capital is $1-\mu\alpha$. Thus the upward bias introduced in the measurement of the Solow residual by the presence of market power disappears if cost based shares of labor and capital are used.

However, in the presence of increasing returns to scale there would be a bias even if the cost based Solow residual is used. In the presence of fixed costs, because most firms

would be operating on the declining portion of their average cost curves, the cost based share of labor would again understate the contribution of labor. Although the cost based residual would adjust variations in the labor input to some extent, the residual itself would rise with every increase in output, introducing an upward bias in its measurement.

Other sources of bias

There are other possible explanations for the failure of invariance (Hall 1990). Procyclicality could also occur because the exogenous variable or instrument used to test invariance could be causally related to stochastic shifts in technology. An example of this could be when thick market externalities exist amongst industries. In such a case an increase in the demand of the output of one industry could trigger off technological change in other industries. Errors in measurement of the inputs and output provide another explanation for the failure of invariance.[7] A third potential source of bias is the difference between the capital employed by any firm and the capital it actually utilizes in any given period (Tybout, 1991).

Hall's methodology

Hall uses the expressions for the calculation of the Solow residual in the presence of imperfect competition and IRS to estimate econometrically the markups of price over marginal cost and the degree of returns to scale. According to Abbott, Griliches and Hausman (1989), Hall's estimates are likely to be upward biased because the estimation procedure fails to take into account the differences in the capacity utilization of inputs. This amounts to the omission of a relevant variable. This problem can be overcome by using an appropriate instrument or the introduction of a capacity utilization variable. Further, the maintained hypothesis of constant returns to scale, used by Hall in his calculations, seems unacceptable in the light of the strong evidence of increasing returns derived from his own studies. As noted earlier, assuming CRS in the presence of DRS or IRS would lead to biased estimation.

Klette (1993) resolves this inconsistency, by estimating the markup and the degree of returns to scale, simultaneously rather than separately. Incorporating the concept of quasi-fixed capital in the short run profit maximization problem of the firm, Klette shows that the

[7] Measurement errors are very important but there is not much that can be done about these in a deterministic framework. The measurement of capital is an extremely important element of any TFP exercise but we will not address this issue here as this is beyond the scope of the paper.

estimation procedure can be modified to include the estimation of the degree of returns to scale. The model developed by Klette, by considering the short run problem of the firm, also allows for the possibility of under utilized capital.

This idea is extended by Srivastava (1996) to address the problem of biases arising due to the failure to account for capacity utilization rates of labor. It is proposed that because of the considerable costs associated with its recruitment and retrenchment, labor should also be treated as a quasi-fixed input in the Indian case. The model is based on the short run profit maximization problem of a firm that uses two quasi fixed inputs, labor and capital, with infinite adjustment costs. This model allows for the simultaneous estimation of capacity utilization, scale economies and profit margins while taking into account the capacity utilization problem.

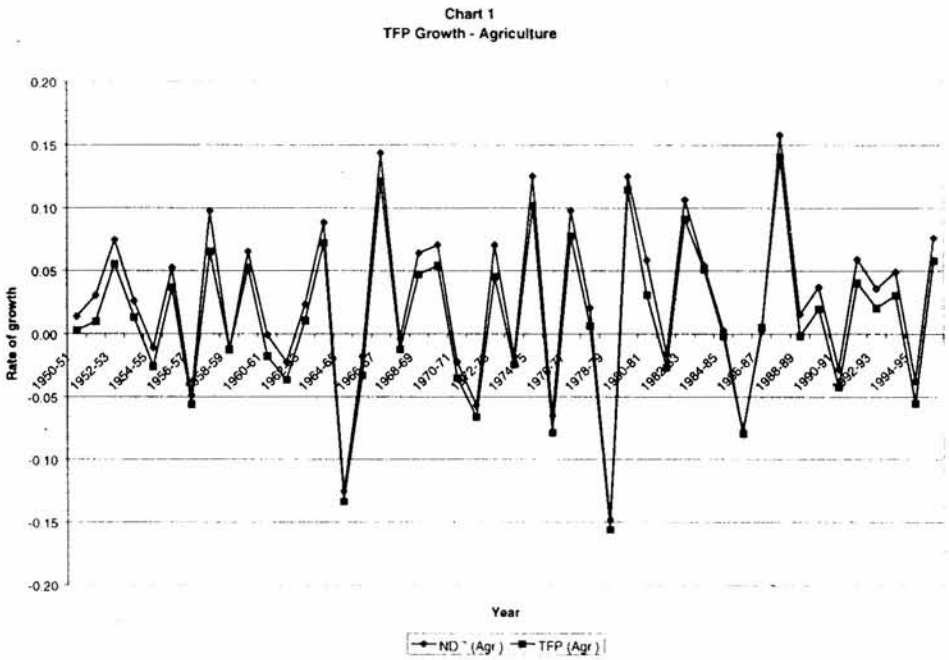
The above discussion suggests that the procyclical behavior of the Solow residual can be explained in terms of the failure of the assumptions of competition and CRS. The problems of capacity utilization can be solved to a certain extent by considering the short run optimization problem of a firm in a production function framework. In the next section we will present an example where an attempt is made to account for capacity utilization in the growth accounting framework. The result, as we shall see, is not very satisfactory. However, if improved capacity utilization rates are being captured as productivity gain this is quite acceptable, particularly in the Indian case where under utilization of capacity is a chronic problem.

4. FOUR EXAMPLES

In this section we present empirical evidence from India which suggests that the Solow residual is not exogenous and that this is, most probably, because the assumptions of perfect competition and constant returns to scale do not hold. We present three sets of TFPG estimates based on the growth accounting approach - one from Indian agriculture, one from Indian industry and one that uses aggregate GDP - that clearly show the pro-cyclicality of the TFPG estimates. The fourth example, from Indian manufacturing, shows that correcting for market power reduces the pro-cyclicality of the TFPG estimates.

Example 1 - *TFPG estimates based on net domestic product in Indian agriculture*

The example presented in this section is based on Sharma (1999) who presents TFPG

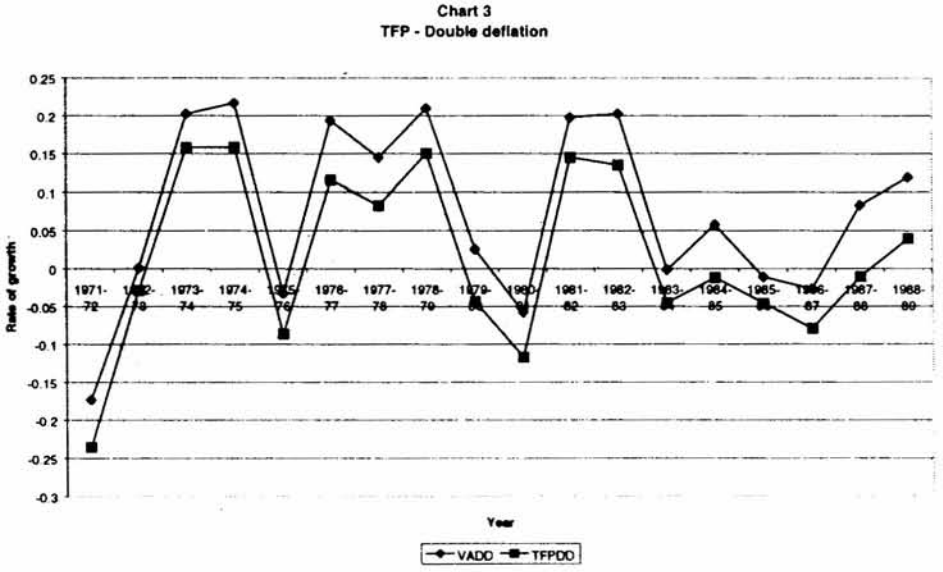


estimates for the period 1950-51 to 1996-97. Sharma's analysis is based on Dholakia and Dholakia (1993) for the period up to 1988-89 and on his own calculations for the period 1990-91 to 1996-97. The study show that periods of high agricultural growth (1980-81 to 1989-90) are characterized by relatively high contributions of TFPG and periods of relatively low growth (1990-91 to 1996-97) by lower contributions of TFPG. He concludes that the slowdown of agricultural growth during the 1990s is *because of the slowdown in TFPG.* Based on the evidence presented, we are not convinced that this conclusion is justified. Using the data used by Sharma (1999) we have plotted the growth rates of net domestic product in agriculture and TFP in Chart 1. The pro-cyclicality of the TFP residual is obvious from the chart. The coefficient of correlation between TFPG and the growth of agricultural NDP is 0.99.

Clearly, it is unlikely that the observed changes in agricultural growth rates are resulting instantaneously from exogenous technological shocks. In view of this we are inclined to conclude tnat the endogeneity of the TFPG estimates is a result of the failure of one or more of the required assumptions.

Example 2 - *TFPG estimates based on manufacturing value added*

This is example is based on the TFPG calculations presented by Balakrishnan and Pushpangadan (1994)[8]. As noted earlier, in this paper B&P drew attention to the importance of double deflation of value added. We discuss here the results presented by them in Table 2 of their paper. The calculations are based on ASI data for the period 1970-71 to 1988-89. It is these results that turned Ahluwalia's (1991) finding of a "turnaround" on its head. The findings of this study are well known and we will not repeat them here. Our interest here is not, however, in the TFPG estimates but in the methodology. In Charts 2 and 3 we present B&P's data on growth rates of value added and their estimates of TFPG. Chart 2 is based on the single deflation of value added (VASD) and Chart 3 is based on the preferred (double deflated) measure of real value added (VADD). In both cases we also present the

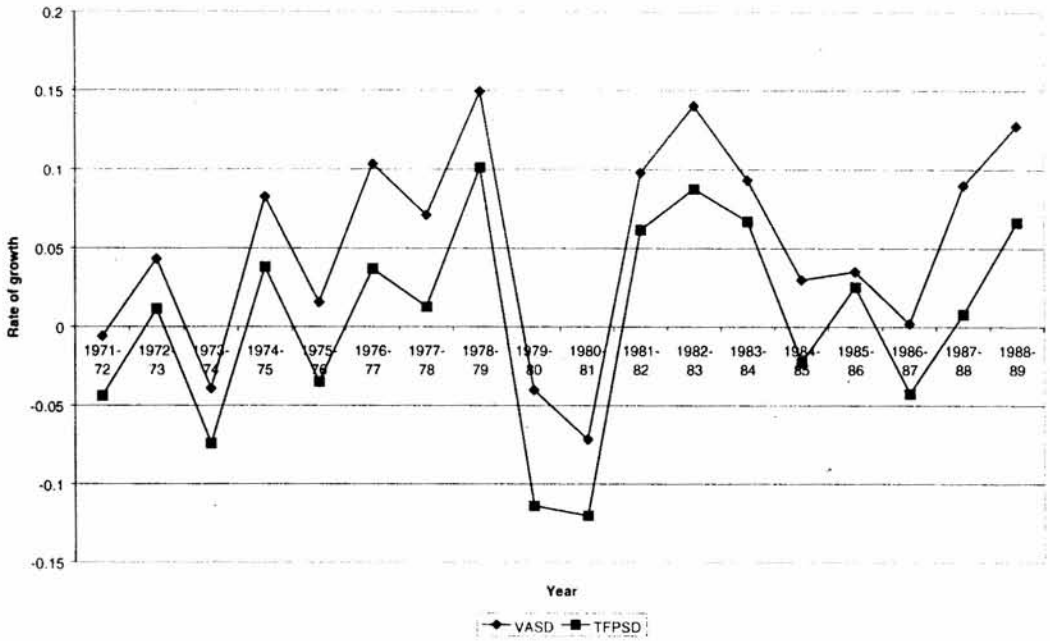


corresponding TFPG estimates, TFPGSD and TFPGDD.

The pro-cyclical behavior of the Solow residual is again clearly evident, regardless of what

measure of value added is used. The correlation coefficients are 0.96 (in the case of VASD) and 0.99 (in the case of VADD). We are again inclined to conclude that the Solow residual is not exogenous and that this is because of the failure of one or more of the relevant assumptions.

Chart 2
TFP - Single deflation



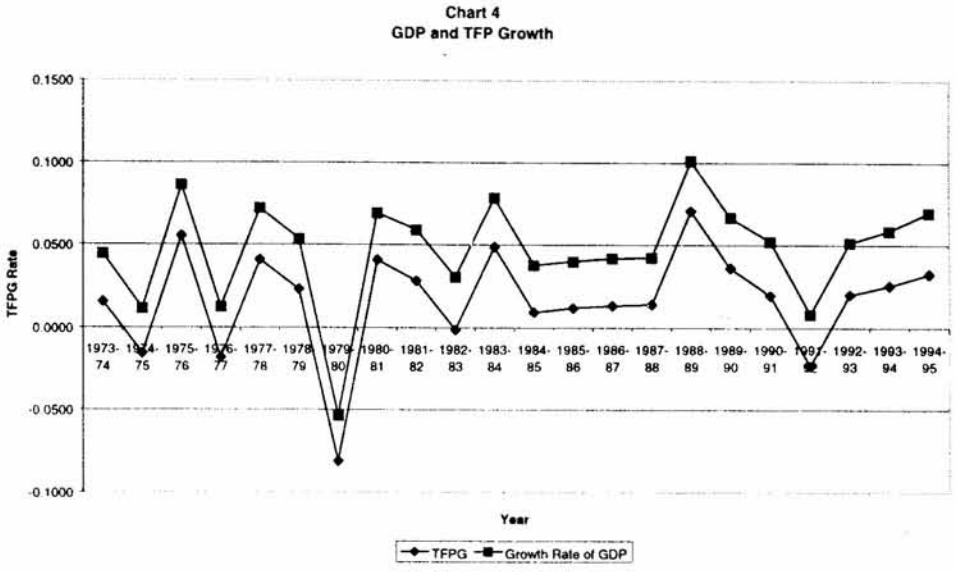
Example 3 - *TFPG estimates based on GDP*

The example presented here is based on a study by Srivastava (1999), for the period 1973-1995. The study uses National Accounts data for GDP and capital stock and NSSO data for labor. The estimated TFPG rates range from a low of -8.1% in 1979-80 to a high of 7.1% in 1988-89. The average TFP growth rate during the period is an estimated 1.66% per annum. The sub-period averages show that TFP growth during the 1980s was considerably higher than during the 1970s. The estimated average TFPG rate of 2.7% per annum for 1980/81-1989-90 is markedly higher than the average growth rate of 0.3% during 1973/74-1979/80. This appears to confirm the findings of Ahluwalia (1991) and Srivastava (1996). Further evidence of this is provided by a comparison of the average for the period 1985/86-1994/95 (1.8%) with the average for 1973/74-1984/85 (1.2%).

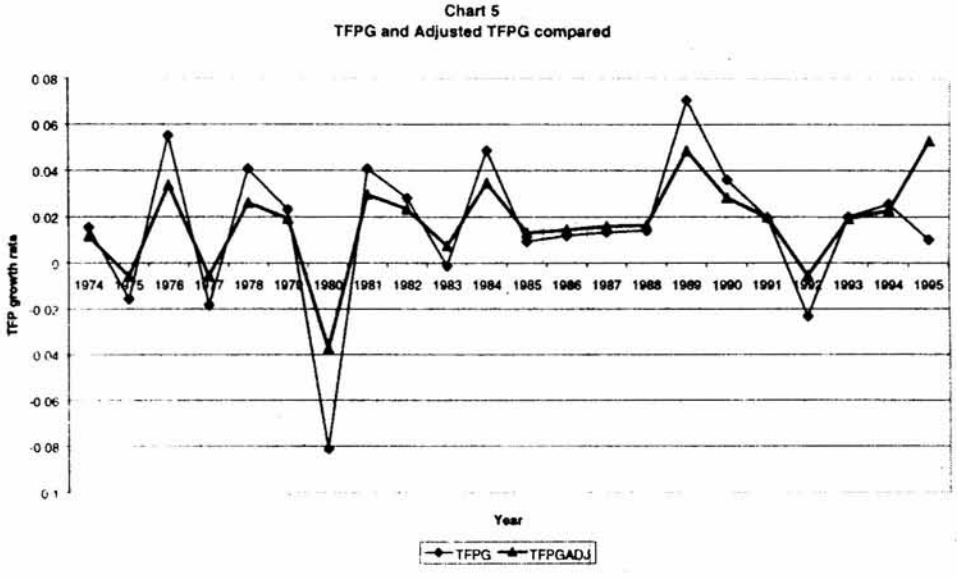
The relatively high rates of GDP and industrial sector growth achieved during the post-reform years have been slowing down since about 1996. The analysis also suggests that TFPG rates that had picked up during the 1980s have become lower during the 1990s. This

[8] Hereafter referred to as B&P.

might lead one to conclude that lower TFPG rates have led to lower growth rates. Again, however this conclusion would probably be wrong as the causality is not clear.



In Chart 4 we present a plot of the GDP growth rates and the estimated TFPG rates. The pro-cyclical behavior of the TFP residual is again evident and the correlation is almost perfect. Srivastava (1999) also attempted a correction for capacity utilization using the Wharton methodology. This reduces the magnitude of the pro-cyclicality but not the direction. Chart 5 shows a plot of unadjusted TFP growth rates (TFPG) and TFP growth rates adjusted for capacity utilization (TFPGADJ).

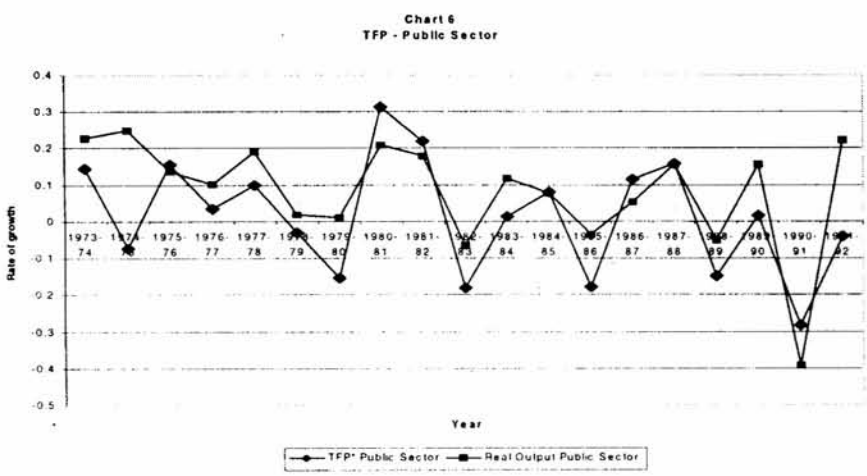


We are again inclined to believe that the Solow residual as estimated in this study is endogenous and this is because of the failure of either the assumption of perfect competition or constant returns to scale.

Example 4 - *TFPG estimates based on gross output with a correction for market power*

The example in this section is based on the disaggregated TFP indices calculated by Rao (1996b). In this paper Rao presents separate TFPG indices for public sector companies, large private sector companies and small private sector companies with the purpose of comparing these with estimates based on single- and double-deflated value added (Table 3: 3180). The study is based on ASI data and covers the period 1973-74 to 1992-93. He makes a correction for monopoly power for the large- and small-scale private sector and reports TFPG estimates based on this adjustment. He makes no adjustment for market power for the public sector. Charts 6, 7 and 8 present TFPG and output growth rates for the public sector, large private sector and small private sector respectively. It is evident from the charts that the behavior of the TFPG estimates is significantly less pro-cyclical than in the three examples presented earlier. The coefficient of correlation is the highest in the case of the public sector estimates (0.72), lower in the case of the estimates for the large private (0.35) and the lowest in the case of the estimates for the small private sector (0.16).

It appears that the correction for market power reduces the bias in the growth accounting estimates of TFPG. Any remaining correlation is probably because of biases due to returns to scale, underutilization of capacity and inadequate correction for the bias due to market power.



5. CONCLUSION

In this paper we look at the problems associated with estimation of TFPG using the growth accounting framework. Specifically, we focus on the potential biases in the Solow residual in the presence of imperfect competition, absence of constant returns to scale and underutilization of capacity. We present examples from existing studies that use the traditional growth accounting method for measuring total factor productivity. Ideally the growth accounting technique should yield an estimate of TFPG that is exogenous to the rate of growth of output. Any departure from these assumptions and/or an error in the measurement of inputs or outputs could lead to a procyclical bias in the measurement of the Solow residual. The presence of such a positive correlation between productivity and output often leads observers to conclude erroneously that there is a causal relationship between the two variables. In our view, such a positive correlation is often an indicator of the failure of the required assumptions. Although our "proofs" of the proposition are by no means rigorous, they are quite convincing. At the very least, it is clearly established that we learn nothing new if we calculate TFPG in the traditional manner. We may just as well look at the rates of growth of output.

The following conclusions follow from the four examples presented in the paper. First, if the existence of market power or non-constant returns to scale is not accounted for, the Solow residual shows a procyclical bias irrespective of the sector under study. In the Indian case this is evident in agriculture and manufacturing as well as for aggregate GDP.

From the second example we can infer that both the single deflation method as well as the double deflation method yield estimates of the total factor productivity residual that are procyclical displaying a near perfect positive correlation with the rate of growth of output. This is despite the fact that the single deflation method would generally give higher estimates of total factor productivity than the double deflation method.

Third, adjustment of the capital stock for capacity utilization rates reduces the extent of the procyclical bias but does not eliminate it. To eliminate the biases resulting from the presence of imperfect competition and scale economies we need consistent and reliable estimates of the markup and the returns to scale parameter. Micro level data is essential for the simultaneous study of the markup and the degree of departure from constant returns to scale. Industry level data are affected by externalities that are very different from the scale economies experienced by an individual firm. Rao (1996b) attempts to remove a part of this

bias by correcting for the presence of market power in Indian manufacturing. Example 4, based on Rao's figures, reveals that such a correction reduces the procyclical bias to some extent.

It is extremely important to get correct estimates of TFP growth rates if such analysis is to serve any useful policy purpose. This would help us understand better the driving force behind growth in output and whether a more concerted effort is needed to facilitate improvements in productivity through better policy planning. In view of all the data and estimation problems involved, no one set of numbers can expect to be the final word on the subject. We strongly feel that researchers in the field should not adopt dogmatic positions about the superiority of one approach over another. Rather, the attempt should be to use different approaches and techniques to obtain robust results.

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