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Abstract

The important contribution by Basu and Fernald (European Economic Review, 2002, 46) shows that, in practice, there is a statistically significant gap between aggregate productivity and technology that can be attributed to inefficient product and labour markets. This is important, as it implies that the Solow residual is an imperfect index for aggregate technology change. We take a related approach and find that when we control for capacity utilization, time varying markup and account for externalities between industries, by employing a superior system estimator, the gap between the aggregate productivity and technology is shown to narrow considerably.

Keywords: Productivity; Technology; Welfare; Hours; Dynamic-Markups

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1. Introduction

In an influential paper, Basu and Fernald (2002, BF hereafter) show in their study of 34 U.S. private economy industries that during 1959-1989 there is a significant gap between aggregate productivity and technology growth. Indeed, productivity growth may fractionally be higher or lower than actual technological growth due to product markets imperfect competition or resource allocation. A rise in productivity growth above that of technological growth is treated as welfare improving, in that more output is distributed and consumed without changes in technology. Other papers provide evidence on the existence of a wedge between the rate of technical change and factors productivity growth, see Bloch and Tang (1999) and Kumbhakar (2003), for example.

This paper revisits the empirical findings of the aggregate productivity and technology gap (the gap hereafter) by: a) accounting for labour utilization and cyclical variations in the product markets and b) using a more efficient estimation method. While the former points feature in BF's discussions

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as possible ways of explaining their findings[1], studies such as Basu, Fernald and Shapiro (2001), Basu, Fernald and Kimball (2006, BFK henceforth) - which introduce multilevel factor utilization, but not changes in dynamic product-markets - do not return to assess the effect on the gap using the same time scale and methodology. The latter point is contentious in the light of Burnside's (1996) study, which questions the validity of 2SLS to estimate sectoral Solow residuals, suggesting instead the use of a system estimator that accounts for cross-sectoral inter-relations. This paper deals with these shortcomings.

We find that although both factor utilization and dynamic changes in product markets largely account for the gap observed in BF, the dynamic changes in product markets are less important. Furthermore, a large fraction of the gap disappears in BF when we use a 3SLS estimator.

The following section lays out the structure of the empirical model and Section 3 presents the results. Section 4 concludes.

2. Empirical Model

2.1. Technology Estimation

Hall's (1990) cost-minimization procedure implies the firm level growth in output consists of weighted input growth, corrected for imperfect competition, and technological improvements[2]. Hence, for an industry i with j-th input x, the growth in output y is given by

$$\triangle y_t^i = \mu^i \sum_{j=1}^{n} s_t^{i,j} \triangle x_t^{i,j} + \triangle \tau_t^i, \tag{1}$$

where, dropping time, $\mu^i, s^{i,j}$ and $\triangle\tau^i$ denote industry $i's$ markup, the share of input j $(1, ..., n)$ in industry $i's$ gross output and Solow residuals, respectively. Inputs comprise of labour, capital and material. The industry-level gross output technology shocks, $\triangle\tau_t^i$, are aggregated using a weighted sum scheme where each industry carries the weight of its nominal share, w^i, in total (nominal) value added of N industries,

$$\triangle \tau = \sum_{i=1}^{N} w_t^i \frac{\triangle \tau_t^i}{1 - \hat{\mu}^i s_t^{im}}. \tag{2}$$

where $\hat{\mu}^i$, s_t^{im} denote the estimated average industry markup and share of materials in industry i and time t. The fraction $1/1 - \hat{\mu}_t^i s_t^{im}$ converts the estimated gross output technology shocks into value added shocks.

[1] Indeed, BF write in the abstract (page 963) that '[e]mpirically,....gaps are important, even though we abstract from variations in factor utilization and estimate only small average sectoral markups.'

[2] Implicitly, our specification has the obvious advantage of not assuming constant returns to scale and perfect competition in product markets when estimating technical change, unlike Mullen (2001), for example, and studies therein.

The estimation of aggregate technology raises two issues: a) time variation of markups are ignored and b) a lack of control for factor utilization can also overstate the importance of estimated technology growth in (1); a point originally taken up in Solow (1957), but also followed by many studies including Burnside, Eichenbaum and Rebelo (1996), BF and BFK.

For the latter issue, we follow Basu et al. (2001) and BFK and correct for work effort and capacity utilization in (1) by introducing growth in hours-per-worker in the model,

$$\triangle y_t^i = \mu^i \sum_{j=1}^{n} s_t^{i,j}[\triangle x_t^{i,j}] + \beta^i \triangle h^i + \triangle \tau_t^i. \tag{3}$$

The new terms in (3) are β^i and $\triangle h^i$. The former is a composite term with parameters that do not need identification for this exercise and are derived assuming that workers are paid a shift premium when utilization is raised. The latter term is growth in hours-per-worker and enters twice in (3). It first appears (implicitly) in the square brackets in (3), as labour has to be adjusted for hours, since firms use both the number of employees as well as hours-per-worker in production. It then appears as the second term on the right-hand-side of (3) to control for capital utilization and labour effort. The reason why growth in hours-per-worker is a reasonable proxy for labour and capital utilization is through its link with data on over-time pay. A caveat in these estimation is the assumption that there are no adjustment costs to varying factor utilization per se.

To control for cyclical variations in the markup, we assume in (4) that it is composed of $\bar{\mu}^i$, a steady-state value of the markup for each industry, and a cyclical component, the strength of which is captured by the coefficient φ:

$$\mu_t^i = \bar{\mu}^i + \varphi_i z_t, \tag{4}$$

z captures the cyclical movements in the markup. The coefficient φ may be constrained to be the same across industries if cyclical variations in product markets are correlated. Similar specifications are used in Domowitz et al. (1988), Haskel, Martin and Small (1995), Ryan (1997 and 2000) and Choudhary and Orszag (2007) and has not been applied to aggregate technology estimations. We estimate (3) by substituting for (4). Finally, the aggregation procedure in (2) is used to compute our aggregate technology shocks.

2.2. *Productivity Estimation*

Aggregate productivity growth is estimated as the difference between aggregate value-added of the economy, $\triangle v$, in our case value-added in the manufacturing sector, and the sum of share-weighted growth in *primary* inputs, dx^V, so that

$$\begin{aligned} \triangle p &= \triangle v - dx^V, \\ dx^V &= s_l \triangle l + s_k \triangle k. \end{aligned} \tag{5}$$

Here, s_k and s_l denote the shares of capital and labour in output defined as the cost of capital or labour in total value added. These shares need not sum to one. The terms $\triangle l$ and $\triangle k$ are growth in aggregate (i.e., total manufacturing) capital and labour stocks. BF show that by expressing industry-level growth in value-added output in terms capital and labor (*excluding material*), and combining the result with industry level version of (5), there results extra terms explaining the gap. Some of this gap can be due to technology and the rest due to different types of factor reallocation. Aggregate productivity growth is shown to be given by

$$\triangle p = (\mu - 1)\sum_{i=1}^{N}\sum_{j=1}^{n} w^i \frac{s_t^{i,j}}{1 - s_t^{i,m}}[\triangle x_t^{i,j}] + \mu(R^K + R^L) + R_m + R_\mu + \triangle\tau, \tag{6a}$$

$$\mu = \sum_{i=1}^{N} w^j \frac{s_t^{i,m}}{1 - s_t^{i,m}\mu_t^i} \tag{6b}$$

where μ represents the aggregate steady-state markup weighted by the nominal shares of each industry in N industries. The industry markup μ_t^i is estimated using (3) and using (4). The terms R are resource allocation arising from capital, labour, intermediate goods, and imperfect competition, respectively in (6a). Of these, the former two can only be extracted as residuals and the latter two can directly be estimated. It is clear in (6a) that with perfect competition, and hence no resource reallocation terms, growth in productivity and technology are equal.

3. Data and Empirical Evidence

We estimate (3) and (6a) using an updated version (annual data from 1959 to 1996) of BF's dataset[3]. We confine our investigation to 21 manufacturing industries, where technology shocks are most likely to occur and for which we were able to match the manufacturing sector with the NBER industrial dataset for hours. An Appendix containing all the estimations results is available upon request.

[3]Based on Jorgenson, Gollop and Fraumeni (1987), downloaded from Dale Jorgenson's webpage and combined with the data used in BF.

3.1. Estimation with Dynamic Imperfect Competition

We first estimate industry level technology shocks using (3) and (4) (ignoring hours) and then proceed to aggregation using (2). Subsequently, we set 1959 to unity and cumulate the estimated aggregate shocks. The estimation of productivity is based on the procedure in Section (2.2). In Fig. 1 (and in all our plots below), the bold line is aggregate productivity. The thin continuous line replicates BF's aggregate technology using only average sectoral markups[4]. We use 2SLS procedure to each sector's regression, with Hall-Ramey instruments (oil price changes, government defence spending and political party in power) as well as a measure of monetary shocks, as in Burnside et al. (1996) and BFK. The half-broken lines plot aggregate technology using *only* the steady-sate markups, $\bar{\mu}^i$, in (4) - removing the cyclical-markup - and the corresponding technology residuals. Our cyclical variable z is detrended industrial output, using the Hoddrick-Prescott filter, widely used to capture the business cycle and we constrain φ to be same across sectors. The broken line is least restrictive in that markups are time-varying at industry level.

Clearly, the gap changes with dynamic product markets. For example, with average sectoral markups method, as in BF, the gap is bigger during 1965-1985, but smaller thereafter. The 1990 productivity slowdown is sharper using dynamic markups or the actual steady-state markup. Thus, dynamic markups seem to matter, although, as we will shortly find, factor utilization is even more important.

3.2. Estimations with Capacity Utilization

We now introduce hours as in (3) to control for work effort and capacity utilization using the method of estimation in Section (3.1). In Fig. 2, we plot BF's aggregate technology with and without hours.

When labour utilization is not controlled for (the thin continuous line), there is a persistent welfare gap post-1965 and it can attributed to internal economic reorganization, as previously discussed. In the period pre-1965 the opposite is true. When hours are introduced (broken line), the technology level changes on two counts. First, the productivity and technology are closely matched. Second, post-1970 economy displays a productivity growth which has elements of beneficial economic reorganization and also periods where productivity lags behind the technology shocks. Consider the five year period of 1985-1990. BF say that this period benefitted from significant resource reallocation. However,

[4] Our replication looks different from the one in BF Fig. 2, Page 988. In their paper, they mistakenly used the standard Solow residuals instead of the revenue weighted residuals. The corrected plot looks similar to our Fig. 1 above *even* for their 34 industries.

correcting for capacity utilization one concludes that productivity growth was, in fact, technology driven. Therefore, we have two different stories for productivity growth for US manufacturing in this period. This is non-trivial, as it has different policy consequences.

3.3. Estimations with 3SLS

Thus far we have used 2SLS. We now reestimate using system estimation, namely 3SLS, as recommended by Burnside (1996)[5]. Given that shocks are likely to be common and also correlated across sectors due to externalities (as in Caballero and Lyons (1992)), one needs to account for this feature and thus deliver more efficient estimates[6]. We use average sectoral markups and estimate the aggregate technology using the corresponding residuals from the Hall's style regression.

In Fig. 3, we plot the results with and without hours. When we simply replicate BF using 3SLS (the thin continuous line), the gap is far narrower than what is reported in BF. In the case where hours are included, the same is obtained. However, with 3SLS, the story of productivity is rather different to the one obtained using 2SLS, especially post-1970. Indeed, the method of 2SLS shows continuous resource reallocation after 1970. Using 3SLS, the gap disappears until 1980, after which we find that productivity growth is lower than technology growth. This understatement of productivity growth may be due to high adjustment costs; indeed this era is one of computerization. Moreover, using hours and 3SLS method the gap is fully reduced during 1959-1985.

4. Conclusion

In this paper we examined the aggregate productivity and technology wedge as proposed in Basu and Fernald (2002). We find that, once we properly control for the dynamic nature of the product market, capacity utilization and sectoral externalities, the aggregate productivity and technology gap practically disappears. Thus, the picture that emerges is one where factor reallocations seem to play a minor role in the dynamics of productivity growth. This result suggests, therefore, that imperfections and frictions in output and factor markets appear to be less important than previously thought.

[5] Another alternative is GMM system estimation. However, heteroskedasticity and autocorrelation tests at the sectoral level do not reveal significant problems, thus confirming the appropriateness of 3SLS.

[6] Two specification tests (LR and Breusch-Pagan) reject at the 1% significance level the null of cross-sectoral uncorrelated disturbances, thus favouring the system specification against the equation-by-equation estimation.

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5. Appendix

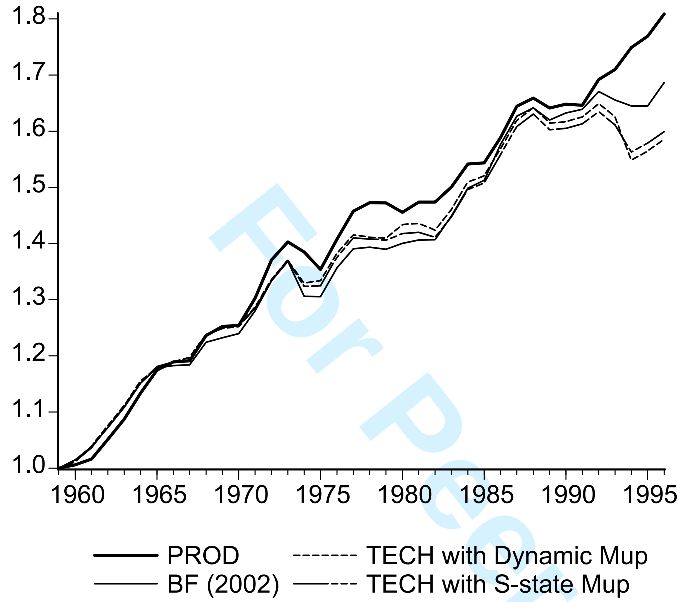

Fig 1. Technology and Productivity with Imperfect Competition

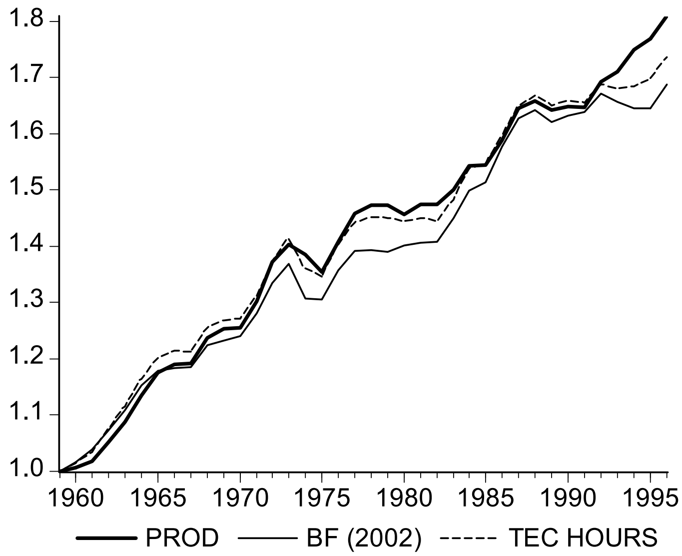

Fig 2. Productivity and Technology with Hours

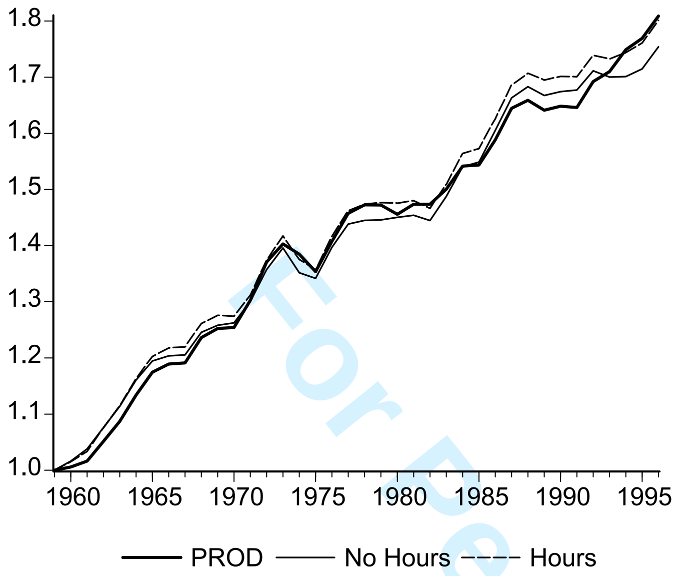

Fig 3. Productivity and Technology Levels Using 3SLS.