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Mind the Gap: a Comment on Aggregate Productivity and Technology

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Abstract

This paper reconsiders the empirical results of Basu and Fernald (European Economic Review, 2002, 46), which suggest a significant and persistent gap between the aggregate productivity and technology levels for the US private business sector. When we control for capacity utilization, time varying markup and use a superior system estimator, the profile of the gap is shown to change considerably.

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

JEL classification: O47; O51; E32; E23

1. Introduction

In an influential paper, Basu and Fernald (2002) show in their study of 34 U.S. private economy industries that during 1959-1989 there is a significant wedge between aggregate productivity and technology growth (PTW hereafter). 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.

This paper revisits the empirical findings of the PTW by: a) accounting for labour utilization and cyclical variations in the product markets and b) using a more efficient estimation method. Factor utilization and dynamic changes in the product markets both feature in Basu and Fernald (2002)'s discussions as possible sources that could explain their findings[1]. Studies, such as Basu, Fernald and Shapiro (2001), Basu, Fernald and Kimball (2006, BFK henceforth) - which introduce multilevel factor utilization and adjustment costs, while still not considering the dynamic product-market - do not return to assess the effect on the PTW using the same time scale and methodology. The issue of estimation method is more contentious in the light of Burnside's study (1996), which questions the

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validity of 2-step estimation to recover individual sectoral Solow residuals and suggests that cross-sectoral inter-relations should be accounted for, in the form of a system estimator. This paper deals with these shortcomings.

Our main finding are: first, that both factor utilization along with dynamic changes product markets largely account for the PTW observed in Basu and Fernald (2002); second, dynamics changes in product markets are less important in explaining the PTW than factor utilization; third, using a 3SLS estimator in Basu and Fernald (2002) a large fraction of the PTW disappears.

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. 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.

The estimation of aggregate technology raises two issues. First, time variations of markups are ignored. Indeed, a technology shock may feedback into product markets by creating winners and losers. Second, 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), Basu and Fernald (2002) 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 in the model,

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

Note that hours enter twice in above (3), as labour has to be adjusted for hours in the square brackets in (3)[2].

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. This specification is used in Domowitz et al. (1988), Haskel, Martin and Small (1995) 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 the residual of the difference between aggregate output and input growth rates. It 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 share-weighted growth in *primary* inputs,

$$\triangle p = \triangle v + s_l \triangle l + s_k \triangle k. \tag{5}$$

Here, s_k and s_l are 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, a contrasting difference to Solow residuals. The terms $\triangle l$ and $\triangle k$ are growth in aggregate (i.e., total manufacturing) capital and labour stocks. Basu and Fernald (2002) show that when they express industry-level growth in value-added output in terms of main inputs, namely capital and labor (*excluding material*), and combine the result with industry level version of (5), they find extra terms which explain the difference between productivity and technology. Some of this difference can be due to technology and the rest due to factor reallocation. Aggregate productivity growth is shown[3] 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

In this Section we estimate (3) and (6a) using an updated version (annual data from 1959 to 1996) of Basu and Fernald (2002)'s dataset[4]. 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 data. Table 1 present some descriptive statistics of the estimations carried out[5].

3.1. Estimation with Dynamic Imperfect Competition

In this section, we first estimate industry level technology shocks using (3) and (4), then estimate aggregate shocks using (2), ignoring hours for the time being. We then set 1959 to unity and cumulate thereafter 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 Basu and Fernald (2002) and plots aggregate technology using average sectoral markups and the residuals from (3)[6]. We apply a 2SLS procedure to each sector's regression, with the usual 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, see these papers for details. The half-broken lines plot aggregate technology using *only* the steady-sate markups, $\bar{\mu}^i$, in (4) - the cyclical element of the markup is removed when aggregating - and the corresponding technology residuals from (3). Our cyclical variable z is detrended industrial output, using the Hoddrick-Prescott filter, widely used to capture the business cycle. Here, we constrain φ to be same for the manufacturing sector. Finally, the broken line is the least restrictive estimation of technology, where the markups are time varying at industry level.

The profile of the PTW is different with dynamic product markets. Generally, post 1965 period is generally dominated by a PTW. Using the average sectoral markups method, as in Basu and Fernald (2002), the PTW is bigger during 1965-1985, but smaller thereafter. The 1990 productivity slowdown is much sharper using dynamic markups or the actual steady-state markup. The message is that dynamic markups do matter significantly for the PTW, contrary to footnote 27 of BFK. However, as we will shortly find, factor utilization is even more important.

3.2. Estimations with Capacity Utilization

In this section we introduce hours as in (3) to control for work effort and capacity utilization. The method of estimation is as in (3.1). In Fig. 2, we plot Basu and Fernald (2002)'s aggregate technology with and without hours.

When labour utilization is not controlled for (the thin continuous line), there is a persistent welfare PTW post-1965 and it can attributed to internal economic reorganization as previously discussed. In the period pre-1965 the opposite is true[7]. When hours are introduced (broken line), the profile of technology level has two distinguishing features. 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. Using, Basu and Fernald's result, one may conclude that this period benefitted from significant resource reallocation. However, correcting for capacity utilization one concludes that productivity growth was largely driven by technology shocks. 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 the 2SLS to estimate our model, as in Basu and Fernald (2002). In this section we reestimate the PTW using system estimation, namely 3SLS, as recommended by Burnside (1996)[8]. 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[9]. 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 Basu and Fernald (2002) using 3SLS (the thin continuous line), the PTW is far narrower than what is reported in Basu and Fernald (2002). 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 PTW 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 PTW 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 wedge 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.

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Notes

[1]Indeed, Basu and Fernald (2002) write that '[e]mpirically, we find that these gaps are important, even though we abstract from variations in factor utilization and estimate only small average sectoral markups."

[2]Burnside et al. (1996) correct for capital utilization by means of industrial electrical use, but we follow here BFK's methodology, see the paper for a full derivation.

[3]There is an extensive proof in Basu and Fernald (2002) which we shall not reproduce. See Eq (24).

[4]Based on Jorgenson, Gollop and Fraumeni (1987), downloaded from Dale Jorgenson's webpage and combined with the data used in Basu and Fernald (2002).

[5]All the estimation results are available upon request.

[6]The reader will notice that our replication looks different from the one in Basu and Fernald's (2002) Fig. 2, Page 988. This is largely due to the fact these authors mistakenly used the standard Solow residuals instead of the revenue weighted residuals. Their corrected plot looks similar to our Fig. 1 above *even* for their 34 industries.

[7]There could be a cyclical pattern here, i.e. internal-organization may induced by the business cycle. We explore this possibility in future work.

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

[9]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. This is also confirmed by a Hausman-type test of 2SLS against 3SLS.

5. Appendix

Table 1 - Descriptive Statistics

Estimated Values	Min	Max	Mean
Aggregate Productivity	-0.018	0.066	0.022
Aggregate Technology With:			
Average Markup (BF, 2002)	-0.022	0.064	0.019
Dynamic Markup	-0.041	0.060	0.016
Steady-State Markup	-0.046	0.059	0.017
2SLS With Hours	-0.017	0.064	0.021
3SLS With Hours	-0.020	0.063	0.021
3SLS Without Hours	-0.016	0.058	0.021

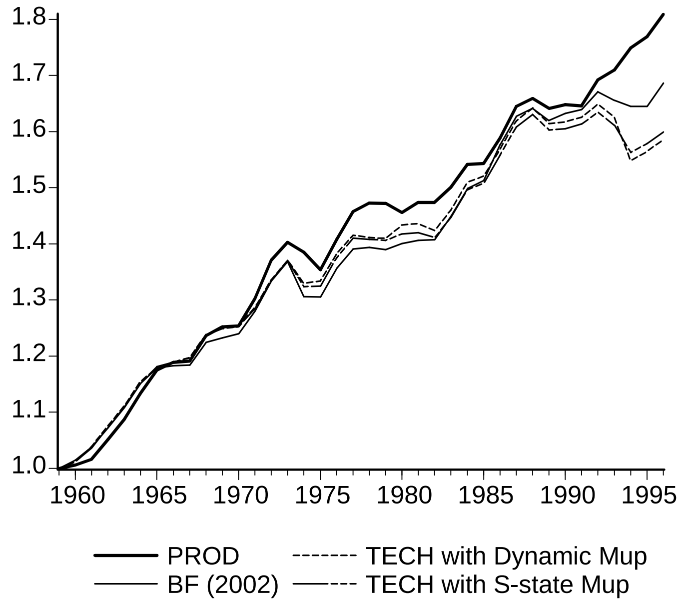

Fig 1. Technology and Productivity Levels with Imperfect Competition

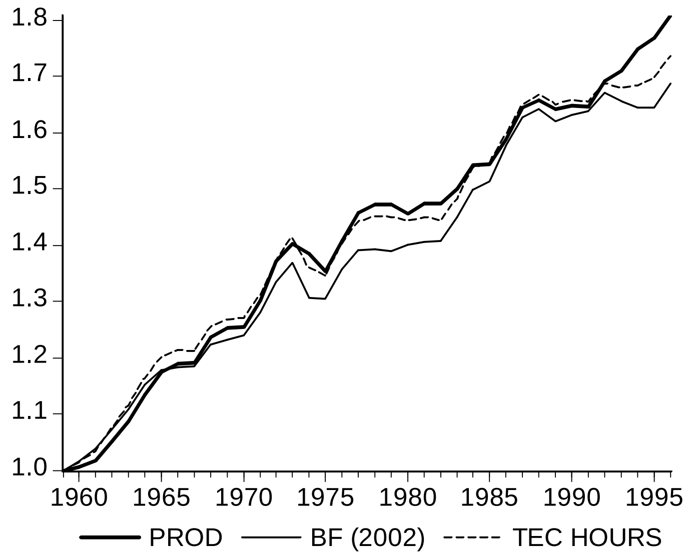

Fig 2. Productivity and Technology with Hours

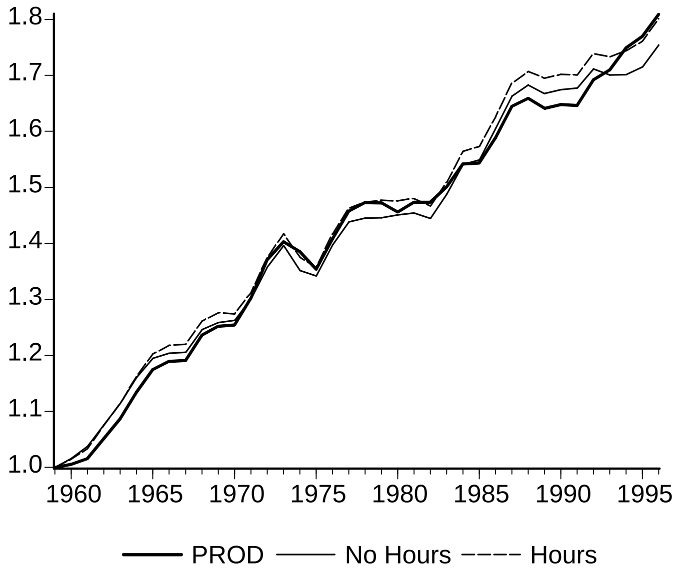

Fig 3. Productivity and Technology Levels Using 3SLS.