Unobserved Factor Utilization, Technology Shocks and Business Cycles

Utilizzo non osservato dei fattori, shock tecnologici e ciclo economico

Domenico J. Marchetti
Banca d’Italia, Servizio Studi

Francesco Nucci
Università di Roma “La Sapienza”, Dipartimento di Contabilità Nazionale

Riassunto: Questo lavoro esamina il comportamento prociclico della produttività totale e l’impatto degli shocks tecnologici sull’impiego dei fattori produttivi. Usando dati panel a livello d’impresa, viene stimato con il metodo GMM un modello che consente di misurare la rilevanza empirica di ciascuna delle spiegazioni della prociclicità della produttività e derivare una misura accurata degli shock tecnologici.

Keywords: Productivity, Technology shocks, Factor utilization, Business Cycle.

1. Introduction

The procyclicality of productivity, as measured by the Solow residual, is a firmly established stylized fact of industrialized economies. Yet, assessing the source of such cyclical behavior remains an open issue, which has crucial implications for understanding the main impulses and propagation mechanisms underlying business cycles. The basic mechanism underlying the standard Real Business Cycle model (RBC) suggests that business fluctuations are driven by exogenous technology shocks. Contrary to this view, the potential role of imperfect competition and increasing returns is advocated to explain procyclical productivity, on the ground that this cyclical pattern endogenously originates from demand-driven fluctuations in input. Another important explanation proposed in the literature hinges on the variability of unobserved factor utilization over the cycle. It is important to realize that the explanations proposed in the literature to account for the procyclical productivity are not mutually exclusive. However, a powerful test for assessing the relative merits of economic models has been recently suggested. Basu et al. (1998) and Gali (1999) have provided evidence that favourable technology shocks reduce input use in the short-run. The finding of a negative contemporaneous relationship between inputs and technology shocks is hard to reconcile with the RBC paradigm. On the contrary, a negative contemporaneous relation between labor and technology shocks is fully coherent with business cycle models featuring sticky prices.

Using firm-level panel data from Invind (Banca d’Italia) and Centrale dei Bilanci, this paper deals with the procyclical productivity puzzle and it also provides strong evidence on the response of input use to a technology improvement. As in Basu and Kimball
The theoretical model motivating our empirical framework allows us to control for all the potential sources of procyclical productivity. In particular, by estimating the model with GMM techniques developed for panel data, we are able to isolate the contribution to the Solow residual of variable labor and capital utilization, of imperfect competition and increasing returns and of technology shocks. Moreover, we obtain a highly refined measure of technology shocks, where all inappropriate components are net out. We investigate the cyclical properties of this measure and, importantly, the impact of input use (employment, hours and factor utilization) to a technology improvement. A negative relationship clearly emerges. To explore the issue further we isolate in the sample the firms where sticky prices are a major feature: indeed our result is stronger, lending support to explanations of business fluctuations of the new-Keynesian type. We also compare our technology measure with other information available at the firm level: the number of patents and the expenditure on R&D.

This paper is organized as follows: section 2 briefly describes the theoretical framework and the basic empirical specification; section 3 illustrates the data and the estimation techniques and presents the main results.

2. The model and the empirical specification

Our theoretical framework relies primarily on the model developed by Basu and Kimball (1997), which simultaneously allows for the departure from perfect competition and constant returns to scale and for the variability in the intensity of factor use. Using a firm’s cost minimization set-up, where unobservable labor effort and capital utilization are explicitly considered, algebraic manipulation of the first order conditions leads to a production equation where the right-hand side is augmented with all the elements that are potential sources of procyclical productivity. Clearly, the intensity of input use over the cycle is not observable. Yet, we exploit the fact that in minimizing costs the firms operate both on observed and unobserved margins. Therefore, in equilibrium marginal benefits of any input, observed or unobserved, are equal to marginal costs. This implies that variation in unobserved input utilization is directly related to the change in observed input. Following Basu and Kimball (1997), the cost minimization problem of the firm is formulated as follows:

\[ \min_{E,U,H,I,M} \int e^{-rt} \left[ W^G(H,E) + P_M M + W^L \Psi(A/L) + P_I K J(I/K) \right] dt \]

subject to

\[ Y = Z F \left[ (UK)^{c_U} (EHL)^{c_E} M^{c_M} \right], \quad \dot{K} = I - \delta(U) K; \quad \dot{L} = A. \]  

Variables are the following: \( Y \) is gross output, \( L, H \) and \( E \) denote, respectively, employment, hours and hourly effort; \( K, U \) and \( I \) are, respectively, the capital stock, its utilization and gross investment; \( M \) are intermediate inputs and \( A \) represents net hiring. \( W^G(H,E) \) is total compensation per worker; \( W^L \Psi(A/L) \) and \( P_I K J(I/K) \) are the adjustment cost of, respectively, changing employment and capital stock; \( P_M \) and \( P_I \) are the price of materials and investment, while \( \delta \) is the rate of capital depreciation; \( Z \) is the level of output-augmenting technology; \( c_L, c_K, c_M \) denote cost shares of each input.

Subject to the technical constraint, represented by a generalized Cobb-Douglas production function, the firm minimizes costs over the choice of net hiring (\( A \),
investment \((I)\), hours \((H)\), effort \((E)\), capital utilization \((U)\) and materials \((M)\). After setting up the Hamiltonian for this problem, the first order condition of this problem can be obtained. Some tedious algebra yield the following log-linearization of the production function, where lower-case letter denote logarithms:

\[
d y = \gamma \, d x + \gamma \, \zeta \, c_L \, d h + \frac{\gamma}{1 + \Delta} \, c_K \, (d p_M + d m - d p_f - d k) - \frac{\gamma}{1 + \Delta} \, j \, c_K \, (d i - d k) + d z; \tag{2}
\]

\(d x\) is the cost-share-weighted observed input growth: \([c_R d k + c_L (d l + d h) + c_M d m]\); the cost shares are readily measurable and they are part of the explanatory variables; conversely, \(\gamma\), \(\zeta\), \(\Delta\), and \(j\) are the structural parameters to be estimated. In particular, \(\gamma\) represents the degree of returns to scale, \(\zeta\) is the elasticity of hourly individual effort to hours, \(\Delta\) is the elasticity of the marginal depreciation of capital in response to capital utilization and, finally, \(j\) is the elasticity of the marginal cost of adjusting capital. Equation (2) is thus our empirical specification. Once the parameters are estimated, measures for changes in labor and in capital utilization can be easily calculated (respectively \(de\) and \(du\)). Importantly, the estimated residuals \(dz\) of the production equation (2) are our refined measure of technology shocks.

3. Data and estimation results

In order to account for the substantial heterogeneity across firms, we estimate equation (2) using firm-level panel data. To our knowledge, this is the first empirical study on the issue of procyclical productivity conducted on microeconomic data. We rely upon data on Italian manufacturing drawn from two high quality sources: Invind (Banca d’Italia) and Centrale dei Bilanci. We construct an unbalanced panel of about 1,000 firms with the entire sample covering the period 1984-1997. Estimations are conducted using the generalized method of moments (GMM) estimator for panel data. This method was shown to be efficient within the class of instrumental variable estimators for panel data. Indeed, due the endogeneity between input growth and technology shocks, suitable instruments have to be selected. We use the current change of real exchange rate and of materials price, the current change in manufacturing good orders (proxying for demand; Source: ISAE’ s surveys) and a VAR-based measure of monetary shocks. Moreover, we use as instruments the lagged values of the explanatory variable dated \(t-2\) and \(t-3\).

The estimation results are reported in Tab. 1; they refer to the estimation on the whole sample (manufacturing) and on sub-samples referring to firms producing, respectively, non-durable and durable goods. The parameters have always the expected signs and they are in general statistically significant. A notable result is that returns to scale (\(\gamma\)) are close to constant. Moreover, we find evidence that when hours worked by an individual increase (as in booms), individual effort increases but less than proportionally. Costs of adjusting capital are estimated to be convex and when capital utilization rises, capital depreciation increases in a convex fashion. The contribution of variable factors use to Solow residual is estimated to be about 12 \%, explaining a large part of its cyclicity.

The sum of the residuals \(dz\) and the parameters referring to the control dummies \((i.e.\ sectors\ and\ years)\) represents our refined time-varying measure of technology change at the firm-level. Since our data contain information on the number of the patents held by the firm and by its expenditure on R&D, we investigated the link between these
measures of technology and our own. Importantly, a significant link exists among them. Subsequently, we examined some statistical feature of our measure of technology shock: interestingly, the probability of technological regress according to our measure \((d_z < 0)\) is largely inferior to that of the Solow residual: the implausibility of frequent technological regress in real economies makes this result appealing. Moreover, we compared the cyclical behavior of our measure with that of the Solow residual: not surprisingly, no matter which cyclical indicator we use (sectoral or aggregate production, GDP), the degree of cyclicality drops considerably, yet without vanishing.

The next investigation we pursue concerns the response of firm ’s inputs to technology improvements. We regress several measures for input changes (total hours: \(dh+dl\), employment: \(dl\), all factors utilization: \(du+de\)) on our firm-level, time-varying technology change. The estimation results (Tab. 2) indicate that technology improvements negatively impact on inputs. The estimates for the entire sample are statistically significant. Moreover, our data enable us to distinguish firms featuring sticky prices from those with flexible prices. The results from sample splitting suggests that the above results are very strong for firms with sticky prices, coherently with business cycle models of the new-keynesian type. We conducted a number of robustness and sensitivity analyses to validate this result and all the evidence lends support to the view that technology improvements are contractionary in the short run.

**Table 1:** GMM estimation from panel data of the augmented production function

<table>
<thead>
<tr>
<th>Dependent variable: (dy)</th>
<th>Entire sample</th>
<th>Nondurables</th>
<th>Durables</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Dx)</td>
<td>1.054 (0.056)</td>
<td>1.012 (0.036)</td>
<td>1.059 (0.045)</td>
</tr>
<tr>
<td>(c_1dh)</td>
<td>-0.404 (0.210)</td>
<td>-0.185 (0.223)</td>
<td>-0.636 (0.167)</td>
</tr>
<tr>
<td>(c_K(dp_M+dm-dp_I-dk))</td>
<td>0.582 (0.190)</td>
<td>0.540 (0.114)</td>
<td>1.054 (0.140)</td>
</tr>
<tr>
<td>(c_K(di-dk))</td>
<td>-0.069 (0.033)</td>
<td>-0.054 (0.020)</td>
<td>-0.029 (0.026)</td>
</tr>
<tr>
<td>Sargan test</td>
<td>62.4 (0.67)</td>
<td>82.3 (0.41)</td>
<td>63.4 (0.76)</td>
</tr>
</tbody>
</table>

Estimated structural parameters of the regression for the whole manufacturing:

\[\gamma = 1.054 (0.056); \quad \zeta = -0.384 (0.200); \quad \Lambda = 0.811 (0.657); \quad j = 0.118 (0.066)\]

**Legend:** Heteroscedasticity consistent s.e. are reported. Sargan is a test of the over-identifying restrictions; \(p\)-value is reported. Wald tests for the the control variables are not reported for lack of space.

**Table 2:** Estimating the response of several input measures to technology changes

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Regressor</th>
<th>Entire sample</th>
<th>Sticky prices</th>
<th>Flexible prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>((dl+dh))</td>
<td>(dz)</td>
<td>-0.86 (0.022)</td>
<td>-0.230 (0.035)</td>
<td>0.020 (0.051)</td>
</tr>
<tr>
<td>(dl)</td>
<td>(dz)</td>
<td>-0.100 (0.015)</td>
<td>-0.207 (0.024)</td>
<td>-0.050 (0.036)</td>
</tr>
<tr>
<td>((du+de))</td>
<td>(dz)</td>
<td>-0.210 (0.033)</td>
<td>-0.430 (0.051)</td>
<td>-0.079 (0.076)</td>
</tr>
</tbody>
</table>

**References**

