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A contribution to the debate

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Biased Technological Change: A contribution to the debate

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Abstract

Antonelli and Quatraro (2010) apply a specific methodology to identify the effects of biased technological change on productivity growth. However, this method has been criticized by Li and Ji (2014). This research note is a reply to their critique.

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1 Three compared models

This section describes three methods to measure total factor productivity (TFP) developed in Solow (1957), Antonelli and Quatraro (2010) and Li and Ji (2014).

Solow (1957) assumes a generic aggregate production function of the form:

$$Y = F(K, L, t), \tag{1}$$

where Y is the output; K is the capital input in physical units; L is the labor input in physical units and t is the technical change i.e. "any kind of *shift* in the production function" (Solow, 1957:312). However, after the contribution of Acemoglu (1998) it is become clear that also a change of endowments of inputs affects the technological change. Therefore, also in Solow (1957) the most general formulation of the total factor productivity (TFP) does not consider the baised technological change (BTC). Although there may emerge some inconsistencies between the claim text and equations (see footnote 2), they have a minor and marginal role in the Solow (1957)'s analysis since BTC identification was not in the propose of the empirical analysis. Moreover, before Acemoglu (1998)'s paper the BTC definition has been offered by Hicks (1932). However, he refers to changes of techniques and not of technologies (Salter 1960).

In further calculations, he implicitly assumes a Cobb-Douglas production function. In this paper I set the same assumption. Solow assumes constant returns to scale, as in the two models analyzed below. Let α_t and β_t define, respectively, the output elasticity of capital and of labor at time t. So, $\alpha_t = 1 - \beta_t$. Solow's TFP can thus be written as:

$$TFP_t^S = F_t = y_t - k_t^{\alpha_t} - l_t^{\beta_t}, \tag{2}$$

where lowercase letters refer to the logarithm of the corresponding uppercase letter variables, e.g. $y_t = \ln(Y_t)$. The superscript S indicates that equation (2) is the TFP identified by Solow. It is clear that the TFP exactly measures the neutral shift effect of technological change.

Antonelli and Quatraro (2010), henceforth AQ (2010), criticized Solow's method. In particular, they point out that equation (2) does not take into account all the possible effects of technological change. More specifically, they state that Solow's methodology does not consider the introduction of BTC as a form of technological change. Indeed, only when the output's elasticity is kept constant can the difference between the historic output, y_t, and the actual theoretical output, $k_t^{\alpha_0} + l_t^{\beta_0}$, measure the effects of the introduction of BTC. That is to say, according to AQ (2010), the correct TFP is:

$$
\begin{aligned}
TFP_t^{AQ} &= y_t - k_t^{\alpha_0} - l_t^{\beta_0} \\
&= y_t - k_t^{\alpha_t} - l_t^{\beta_t} + k_t^{\alpha_t} + l_t^{\beta_t} - k_t^{\alpha_0} - l_t^{\beta_0} \\
&= F_t + k_t^{\alpha_t} - k_t^{\alpha_0} + l_t^{\beta_t} - l_t^{\beta_0},
\end{aligned} \tag{3}
$$

where the superscript AQ indicates that the equation (3) is the TFP identified by AQ (2010). The difference between (2) and (3) comes from a different definition of theoretical output. If the new output of elasticity of the most abundant factor is higher (lower) than the previous one then the TFP_t^{AQ} increases (decreases). Nevertheless, this does not derive from the shift effect *à la Solow,* but from the biased effect of technology. So, I can write the TFP_t^{AQ} as the sum of two effects: the shift effect, TFP_t^S, and the biased effect, BTC_t^{AQ}, that is the object of the AQ (2010) paper. Then:

$$
TFP_t^{AQ} = TFP_t^S + BTC_t^{AQ}. \tag{4}
$$

For this feature AQ (2010) call the TFP_t^{AQ} as the *total-*TFP.

Li and Ji (2014), henceforth LJ (2014), criticized AQ (2010) paper.[1] In particular, they argued that TFP_t^S accounts for non-neutral shifts of the production function.[2] They state that the correct TFP is:

$$
\begin{aligned}
TFP_t^{LJ} &= y_t - k_0^{\alpha_t} - l_0^{\beta_t} \\
&= y_t - k_t^{\alpha_t} - l_t^{\beta_t} + k_t^{\alpha_t} + l_t^{\beta_t} - k_0^{\alpha_t} - l_0^{\beta_t} \\
&= F_t + k_t^{\alpha_t} - k_0^{\alpha_t} + l_t^{\beta_t} - l_0^{\beta_t},
\end{aligned} \tag{5}
$$

where the superscript LJ indicates that the equation (5) is the TFP identified by LJ

[1] This criticism also concerns Antonelli (2006, 2012) and Antonelli and Quatraro (2013). In particular, LJ (2014) reject the AQ (2010) assumption that Solow considers only neutral shifts of the production function.

[2] Probably Solow is unclear in the paper on this aspect but, as I show above, Solow assumes only neutral displacements of the production function. However, the Solow paper may lead the reader to consolidate their wrong interpretation. Below, there are some examples of the above statement. "The reader will note that I have already drifted into the habit of calling the curve of Chart 2 $\Delta A/A$ instead of the more general $\Delta F/F$. In fact a scatter of $\Delta F/F$ against K/L (not shown) indicates no trace of a relationship. So I may state as a formal conclusion that over the period 1909-49, shifts in the aggregate production function netted out to be approximately neutral. Perhaps I should recall that I have defined neutrality to mean that the shifts were pure scale changes, leaving marginal rates of substitution unchanged at given capital/labor ratios" (Solow, 1957:316). "For comparison, Solomon Fabricant has estimated [. . .]. Not only he does the usual choice of weights for computing an aggregate resource-input involve something analogous to my assumption of competitive factor markets, but in addition [...] seem tacitly *assume* (a) that technical change is neutral [. . .]" (Solow, 1957:317).

(2014).[3] The main difference between (2) and (5) is, once again, in the different definition of theoretical output. Similarly to AQ (2010), their proposal leads to two effects: the shift effect and the biased effect.[4] Therefore, with the exception of superscripts, equation (4) holds.

However, the decomposition presented in (5) is in contrast to the rest of the paper. Indeed, if the first part of the paper shows that Solow's method is applicable also in a non-neutral technological contest, the second part of the paper seems to sustain the opposite thesis. Indeed, the equation $TFP_t^{LJ} = TFP_t^S + BTC_t^{LJ}$ is consistent with the idea of AQ (2010).

2 Why the new method is wrong

Equations (3) and (5) show that Solow's method does not calculate the BTC effect on TFP. However, the two models use two different definitions of TFP, therefore there are two possible formulations about the BTC. In particular, AQ (2010) calculate the BTC as follows:

$$BTC_t^{AQ} = TFP_t^{AQ} - TFP_t^S. \tag{6}$$

When BTC_t^{AQ} in a region is above (below) zero, then the direction of the technological activity is right (wrong). This can be observed in equation (3). Assume that an input, e.g. k_t, has a relatively high value and that the corresponding elasticity of output, e.g. α_t, increases (decreases). Thus, under constant return to scale, the other output of elasticity, e.g. β_t, decreases (increases). The biased effect therefore includes two opposite effects. Indeed, the first effect (increase of α_t) implies an increase of efficiency of k_t but the second effect (reduction of β_t) implies the reduction in relative efficiency of l_t. However, by $k_t > l_t$, the first effect is larger. Consequently, the biased effect amplifies (reduces) the total effect. Therefore, the technological change is consistent with the factor endowment. Of course, the reverse is true if the input has a relatively low value.

Using the same methodology, LJ (2014) calculate the biased effect through:

$$BTC_t^{LJ} = TFP_t^{LJ} - TFP_t^S. \tag{7}$$

Also in equation (7) the critical value is zero. When BTC_t^{LJ} in a region is above (below) zero, then the direction of the endowment factors is right (wrong). Then, the technology is

[3] However, a similar method has already been used by Bernard and Jones (1996).

[4] In reality, LJ (2014) do not write the TFP_t^{LJ} with a logarithmic form; so they formulation would not allow split the two effects as a sum.

appropriate whether the technology progress is in accordance with the factor endowment. This can be observed in equation (5). Therefore, the biased effect amplifies (reduces) the total effect. Of course, if the elasticity of the output has a relatively low value, the opposite is true. Note that both wording and intuition of BTC_t^{LJ} are symmetrical to the results in AQ (2010). The only difference between (3) and (5) lies, as already mentioned above, in the explanation of the biased effect.

The TFP calculated with the last methodology is hard to justify. Indeed, calculating the change of production factors to analyze the change in technology is at best audacious. In particular, there are several reasons for which the inputs increase endogenously and only one of these reasons derives from technological change. The production factors, then, vary not only if the technology changes, but also if the relative cost of factors and/or the budget endowment is modified. So, it may happen that the technological activity is characterized by the right directionality but factor endowment is characterized by the opposite directionality (and vice versa). The methodology in LJ (2014) therefore only measures the true biased direction if the factor's budget and the costs are constant over time. These problems do not occur in the methodology developed in AQ (2010).

In addition, even if the change of factors is exogenous, there is no reason to sustain that the increase of a production factor leads to a reduction of the other factor.

As a final remark, the LJ (2014) method might be useful if the focus of the paper is not on technological change but on how the direction of the technology influences the variation of inputs. Indeed, LJ (2014) show how the inputs vary, but they do not provide any information regarding the motivation for this change.

3 Conclusion

In this note, I show that the criticism of LJ (2014) probably derives from a misunderstanding of Solow's paper and it is unjustified. Indeed, after the contribution of Acemoglu (1998), the Solow's framework is insufficient to measure all technological effects on TFP. Nonetheless, the critique that emerge in LJ (2014) implicitly show how the factor endowment changes within a region and if this variation is consistent with the technology in that region. Therefore, using the idea underlying the paper of AQ (2010), LJ (2014) method can to distinguish if the factors' endowment increases by technological reason or by other reasons.

References

[1] Acemoglu, D. (1998). Why do new technologies complement skills? Directed technical change and wage inequality. *Quarterly Journal of Economics*. 113(4), 1055–1089. doi: 10.1162/003355398555838

[2] Antonelli, C. (2006). Localized technological change and factor markets: Constraints and inducements to innovation. *Structural Change and Economic Dynamics*, 17(2), 224-247. doi: 10.1016/j.strueco.2004.05.002

[3] Antonelli, C. (2012). Technological congruence and productivity growth, in Andersson, M., Johansson, B., Karlsson, C., Lööf, H., (eds.), *Innovation and Growth - From R&D strategies of innovating firms to economy-wide technological change*, Oxford University Press, Oxford, pp. 209 – 232. doi: 10.1093/acprof:oso/9780199646685.001.0001

[4] Antonelli, C. and Quatraro, F. (2010). The Effects of Biased Technological Change on Total Factor Productivity: Empirical Evidence From a Sample of OECD Countries. *The Journal of Technology Transfer*, 35(4), 361-383. doi: 10.1007/s10961-009-9134-2

[5] Antonelli, C. and Quatraro, F. (2013). Localized Technological Change and Efficiency Wages across European Regional Labour Markets. *Regional Studies*, 47(10), 1686-1700. doi: 10.1080/00343404.2012.690068

[6] Bernard, A. B. and Jones, C. J. (1996). Comparing Apples to Oranges: Productivity Convergence and Measurement Across Industries and Countries. *The American Economic Review*, 86(5), 1216-1238. doi: 10.1257/aer.91.4.1168

[7] Hicks, J. R. (1932). *The Theory of Wages*, London, Macmillan.

[8] Ji, Y. and Wang, Y. (2014). Some comments on Antonelli and Quatraro's paper of measuring effect of biased technology on TFP. *The Journal of Technology Transfer*, 39(2), 327-335.

[9] Li, P. and Ji, Y. (2014). The effects of biased technological change on total factor productivity: Based on the new perspective of appropriate technology. *African Journal of Business Management*, 8(10), 276-280. doi: 10.5897/AJBM2014.7355

[10] Salter, W. E. G. (1960). *Productivity and Technical Change*, University Press, Cambridge.

[11] Solow, R. M. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics*, 39(3), 312-320. doi: 10.2307/1926047

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