COMMENT

Wan's "New Approach" to Technical Change: A Comment[1]

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Felipe, Jesus, and McCombie, J. S. L.—Wan's "New Approach" to Technical Change: A Comment

This paper questions Wan's (1995, *J. Comp. Econom.* **21**, 3:308–325) proposal for a new assumption-free measure of total factor productivity growth. Wan's measure follows directly as an algebraic transformation of the national income accounting identity, according to which value added equals the wage bill plus profits, and thus there is no reason it should be interpreted as a measure of technical change. *J. Comp. Econom.*, June 1999, 27(2), pp. 355–363. School of International Affairs, Georgia Institute of Technology, Atlanta, Georgia, 30332-0610; and Downing College, Cambridge, United Kingdom. © 1999 Academic Press

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I. INTRODUCTION

In a recent paper in this journal, Wan (1995) proposed a new nonparametric approach to estimating the rate of total factor productivity (TFP) growth. The rationale for his method is twofold. First, the derivation of the traditional growth accounting equation depends on assumptions such as profit maximization and

355

perfect competition. This most probably is inappropriate for a centrally planned economy like China.[2] Second, Wan claims that the conventional approach requires the explicit introduction of time in the production function. This, in the words of the author, "precludes the possibility of studying cross-sectional technical change" (Wan, 1995, p. 309). Furthermore, this practice implies the assumption that technical change is "continuous, exogenous, and smooth" (Wan, 1995, p. 309). Therefore, he proposes what he interprets as a new nonparametric approach, which he sees as the dual to the conventional method of measuring total factor productivity growth by using the production function directly. By "nonparametric," it seems that Wan has in mind a variant of the growth accounting approach whereby the parameters of the production function, e.g., the elasticity of substitution, are not estimated explicitly or required.

In the traditional analysis, ever since Solow's (1957) seminal paper, the marginal productivity conditions and the assumption of perfect competition are invoked to justify the use of factor shares in revenues as weights for calculating the contribution of labor and capital to output growth. Thus, if correct, Wan's approach would avoid some of these limiting assumptions. However, other recent studies that have assumed imperfect competition and sometimes increasing returns to scale have weighted the growth of factor inputs by the factor shares in costs rather than in revenues (Hall, 1990; Basu and Fernald, 1995). The purpose of this comment is to show that the reason Wan does not need to invoke a particular specification of a production function or to assume perfect competition is that his measure of technical progress is derived simply from an accounting identity. This identity is that value added is definitionally equal to the sum of the total compensation of labor and total payments to capital. Since it is an identity, it is compatible with the existence of an aggregate production function, or indeed with the absence of any underlying well-behaved production function (on this, see Fisher, 1993). The problems posed by this identity for the estimation of production functions using value-added data are not new (Simon and Levy, 1963; Simon, 1979; Shaikh, 1974, 1980), but their implications have been largely ignored.

II. WAN'S METHOD

Wan starts by assuming a constant-returns-to-scale technology. If we restrict ourselves to the two-factor input case, the production function is given by $Q_t = f_t(L_t, K_t)$. It will be noted that time does not explicitly enter into this specification. This is because, according to Wan, technical change is defined as having occurred when the functional form changes, i.e., when $f_t \neq f_{t+1}$. In this way, technical change can affect either the functional form or the parameters of the

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[2] See, however, Hu and Khan (1997, p. 108) for a dubious justification of growth accounting for China.
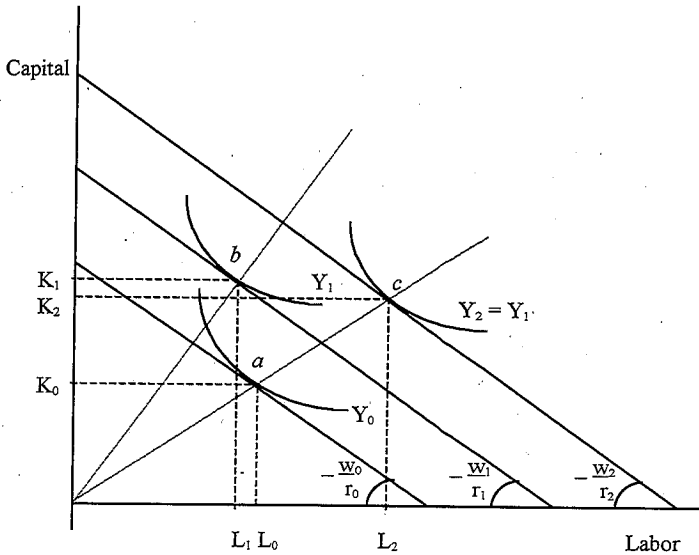
FIG. 1. Wan's measure of technical change without relative factor price changes.

production function, or both. Wan claims that, in the conventional TFP frame-work, "technological changes can only be reflected in varying the values of the parameters of these functions" (Wan, 1995, p. 310).

Wan's procedure is based on the fact that technical change enables a firm to produce the same volume of output with less input. In order to keep matters simple, let us consider the two-factor input case in which the inputs are L and K. Figure 1, which is adapted from Fig. 1 in Wan, p. 311, depicts the isoquants of the production function where point a (coordinates L_0, K_0) with output Y_0 is designated as the base year. The total cost (TC) for producing the observed level of output Y_0 is definitionally given by $Y_0 = TC_0 = w_0 L_0 + r_0 K_0$, where w is the average wage rate, L denotes employment, r is the average profit rate, and K is the stock of capital with all values measured in real terms. Point b (coordinates L_1, K_1) represents the observed output given by another production function, in which the functional form has changed because of technical change. Thus at b, $Y_1 = TC_1 = w_1 L_1 + r_1 K_1$, which is also true by definition. At point c (coordinates L_2, K_2), the same level of output as at b, i.e., $Y_1 = Y_2$, is produced assuming the same level of technology as at a. In other words, the increase in output from Y_0 to Y_2 is entirely the result of increased inputs. For expositional ease, the discussion is confined to the case where the ratio of factor prices does not change. Wan also considers the alternative case.

A measure of technical change (TE) is defined as the difference between the cost of producing Y_2 at c using the same technology as at a and the cost of producing Y_1 using a different technology, but with the base year factor prices,

i.e., w_0 and r_0. Thus, using the cost identities, the increase in total efficiency is given by

$$\text{TE} = (w_0 L_2 + r_0 K_2) - (w_0 L_1 + r_0 K_1). \tag{1}$$

Consequently, this definition of technical change is the saving in costs resulting from the need to use less input at b than would have been used at c as a result of the putative benefits of technical progress. Although $Y_2 = w_0 L_2 + r_0 K_2$ is not directly observable, assume that $L_2 = \gamma L_0$ and $K_2 = \gamma K_0$, where γ is some constant. Then it follows that, with constant returns to scale, the only assumption Wan claims it is necessary to make, $Y_2 = \gamma Y_0$.

The first term on the right-hand side of Eq. (1) may be expressed as $w_0(\gamma L_0) + r_0(\gamma K_0)$. Then

$$\text{TE} = (w_0 \gamma L_0 + r_0 \gamma K_0) - (w_0 L_1 + r_0 K_1). \tag{2}$$

Wan defines the proportionate rate of technical change, or the growth of total factor productivity, as TE divided by the terminal year's level of output, Y_1. Consequently,

$$\text{TE}/Y_1 = [(w_0 \gamma L_0 + r_0 \gamma K_0) - (w_0 L_1 + r_0 K_1)]/(w_1 L_1 + r_1 K_1) \tag{3}$$

or, alternatively, since $\gamma = Y_2/Y_0$ and $Y_2 = Y_1$,

$$\text{TE}/Y_1 = \frac{(Y_1/Y_0)(w_0 L_0 + r_0 K_0) - (w_0 L_1 + r_0 K_1)}{(w_1 L_1 + r_1 K_1)}. \tag{4}$$

Equation (4) is equivalent to Eq. (7) on p. 314 of Wan. Since all the values on the right-hand side of Eq. (4) are observable, Wan uses this expression to calculate the rate of technical progress. He compares the results with those obtained applying Solow's (1957) method, i.e., the growth rate of output minus the growth rate of factor inputs, each weighted by the share in output, using the latter's original data set for the United States (see Fig. 3 on p. 314 of Wan). Wan concluded that: "The trends of the two curves are very similar indeed. Thus Solow's arguments for the plausibility of his results and methodology are also applicable to ours" (Wan, 1995, p. 314).

III. TOTAL FACTOR PRODUCTIVITY GROWTH AND THE INCOME ACCOUNTING IDENTITY

In this section, we show that Wan's method can be interpreted in a more parsimonious fashion under which Expression (4) is not necessarily a measure of technical change. Let us begin by writing the value-added accounting identity in real terms as

$$Y_t \equiv w_t L_t + r_t K_t, \tag{5}$$

where Y denotes output or value added. In writing Eq. (5), we make no behavioral or technical assumptions, such as perfect competition and constant returns, nor do we assume that long-run profits are zero. This equation simply states that total income is divided up between labor income and capital income. The former is wages and salaries and the latter consists of profits, rental payments, and interest payments. Expressing Eq. (5) in terms of exponential growth rates, we obtain

$$y_t \equiv a_t \varphi_{wt} + (1 - a_t)\varphi_{rt} + a_t l_t + (1 - a_t)k_t \equiv \varphi_t + a_t l_t + (1 - a_t)k_t, \quad (6)$$

where φ_{wt} and φ_{rt} are the growth rates of the wage and profit rates, respectively; y_t is the growth rate of value added; l_t is the growth rate of employment; k_t is the growth rate of the stock of capital; and a_t is labor's share of value added, i.e., $w_t L_t / Y_t$. Rearranging (6), we obtain

$$y_t - a_t l_t - (1 - a_t)k_t \equiv a_t \varphi_{wt} + (1 - a_t)\varphi_{rt} \equiv \varphi_t. \quad (7)$$

Two points arise from the derivation in Eqs. (6) and (7). First, Eq. (6) yields directly the growth accounting equation derived from an aggregate production function, but with the important difference that no reference is made to an aggregate production function. This is in stark contrast to Solow's (1957) requirements of profit maximization and perfect competition. Second, the left-hand side of Expression (7) is equivalent to the so-called "Solow residual" (Solow, 1957) and, by definition, it must be equal to a weighted average of the growth rates of the wage and profit rates, where the weights are the factor shares in total income.[3] This simple derivation has important and far-reaching implications for the interpretation of the Solow residual as a measure of technical change (see, for example, Phelps Brown, 1957; Simon and Levy, 1963; Shaikh, 1974, 1980; Simon, 1979; McCombie, 1987; McCombie and Dixon, 1991; Felipe and McCombie, 1997; Felipe, 1998; McCombie, 1998). To summarize, the identity yields the same results as those obtained from an aggregate production function, should such a function exist (see Fisher, 1993, for the necessary stringent conditions). The above expressions show that the value-added accounting identity and the aggregate production function are isomorphic forms, and the latter is simply an alternative way of writing the former. Felipe and McCombie (1997) have termed this the equifinality theorem and have provided a formal proof.

[3] The relationship between the accounting identity and the production function is well known. See, for example, Jorgenson and Griliches (1967). What neoclassical theory tries to do is to provide an economic interpretation of Eq. (7) in terms of productivity growth. This interpretation is provided by an aggregate production function with constant returns to scale together with the conditions for producer equilibrium. Felipe and McCombie (1997) have shown that that is not a testable theory. The reason is that, as pointed out in the text, Eq. (6) is the same equation one can derive by differentiating the production function. This indicates that, in this framework, the elasticities will be always equal to the factor shares and will add up to 1.

As the accounting identity is a more parsimonious form than the production function, which includes the neoclassical assumptions necessary to derive the growth accounting formula, and the Solow residual is completely specified from the identity, we cannot interpret the residual unambiguously as a measure of technical change. Even if the aggregate production function exists, we cannot disentangle empirically the causes of the increase or decrease in the wage and profit rates due to, for example, increasing capital per worker, improvements in x-efficiency, or increasing returns to scale. Furthermore, increases in productivity are both the cause and the effect of long-run increases in wages. The problem is even worse if there is no true underlying aggregate production function because of the insurmountable aggregation problems pointed out during the Cambridge capital controversies (Harcourt, 1969) and by Fisher (1993). The reason is that if the relationship reflects merely the accounting identity, the growth of the input times its factor share does not necessarily measure its contribution, in a causal sense, to the growth of output. We conclude that φ_t in Eq. (7) can only be interpreted unambiguously as a measure of distributional changes, not necessarily in a zero-sum sense.

IV. WAN'S METHOD REVISITED

It is interesting that Wan does not use the marginal productivity conditions, that he makes no assumption about the state of competition, and that parameters such as the elasticity of substitution do not even play an indirect role in his calculations. The reason is that Wan derives his results simply from the manipulation of accounting identities. To see this recall that $\gamma = Y_2/Y_0$ and $Y_2 = Y_1$ and so it follows from the identities that

$$\text{TE}/Y_1 = [(Y_1/Y_0)(w_0L_0 + r_0K_0) - (w_0L_1 + r_0K_1)]/Y_1 \tag{8}$$

$$= [Y_1 - (w_0L_1 + r_0K_1)]/Y_1 \tag{9}$$

$$= [(w_1L_1 + r_1K_1) - (w_0L_1 + r_0K_1)]/Y_1 \tag{10}$$

$$= [(w_1 - w_0)L_1 + (r_1 - r_0)K_1]/Y_1 \tag{11}$$

$$= a_1[(w_1 - w_0)/w_1] + (1 - a_1)[(r_1 - r_0)/r_1], \tag{12}$$

where $a_1 = w_1L_1/Y_1$.

Thus, Wan's measure of technical change is the weighted discrete growth rates of wages and the rate of profit. This is exactly the same measure of technical change that is obtained from Solow's approach using the production function with neutral technical change and from the accounting identity expression (5). The only difference is that Solow uses discrete growth rates defined as $(X_1 - X_0)/X_0$ for any variable X in his calculations, whereas Wan uses $(X_1 - X_0)/X_1$, and so it is not surprising that the estimates are slightly different. Both, however,

ignore the interaction term, which is likely to be quantitatively insignificant (McCombie, 1996).[4] Thus, Wan's finding that his method and that of Solow provide the same results can be taken as nothing more than a test of whether the data set is consistent and as an indication that the two approximations for discrete growth rates do not differ much for short periods. A final caveat is that, as we have noted above, one cannot interpret the weighted growth of wages and the rate of profit as a measure of technical change.

The question arises as to precisely why we have found a formal equivalence between the Solow and Wan residuals. The answer is twofold. First, Wan works from the national accounts accounting identity to derive his residual.[5] As we have seen, this is formally equivalent to the method used by Solow to derive his residual using the marginal productivity theory of factor pricing and assuming perfect competition. However, the manipulation of an identity does not require either of these assumptions, or even the existence of a well-behaved production function.

Second, the accounting identity, as we have emphasized, does not embody any assumptions about the state of competition whatsoever. The rate of profit is the ex post rate of return including any monopoly profits. However, Solow's procedure does, it is true, require the assumption of perfect competition. Thus, from a neoclassical point of view the national accounts data can be used to calculate the residual only if markets are perfectly competitive. What happens if they are not? Let us assume that the labor market is competitive so that the marginal cost of labor is the wage rate (see, for example, Hall, 1988). Let the user cost of capital be r' and let the observed rate of profit be r. Thus total monopoly profits are $(r - r')K$. Thus, we have two accounting identities,

$$\sum p_i Y_i^* \equiv Y \equiv wL + rK \equiv wL + r'K + (r - r')K \qquad (13)$$

and

$$\sum \mathrm{mc}_i Y_i^* \equiv Y' \equiv wL + r'K, \qquad (14)$$

where p_i is the market price of the quantity of the ith good denoted by Y_i^* and mc_i is the marginal cost. Equation (13) is the equation showing how data appear in the national accounts, while in Eq. (14) factor inputs are valued according to their marginal productivities ($\sum \mathrm{mc}_i Y_i^*$ denotes total costs in neoclassical termi-

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[4] The interaction term arises when we consider a multiplicative function. This is the case of the aggregate production function with Hicks-neutral technical progress. The growth accounting equation transforms this product into a sum. If we denote the rate of growth of population as x and the rate of growth of productivity as y, the rate of growth of output is given by $(1 + x)(1 + y) = 1 + x + y + xy$. The interaction term, xy, is a function of the product of two growth rates and, hence, its value is very small.

[5] As indicated in Section II, in one of his samples, he uses the same data set as Solow, which is taken from the national accounts.

nology), and thus the term $r'K$ reflects the normal profits (monopoly profits are zero). The national accounts will be compatible with (13) only under perfect competition. Thus, Solow is correct in using national account data only if markets are perfectly competitive. Otherwise, the hypothetical data in Eq. (14) should be used.[6] Then output elasticities will be the share of wages and normal profits in total costs to the firm (as defined in Eq. (14)), but not the observed total remuneration of the factors in total revenue. It should also be noted that the correct measure of output is Y', not Y. If we were to use the latter, part of the residual would include the growth in monopoly profits, which has nothing to do with the neoclassical measure of technical change.

Two points arise. First, and most important, the use of Eq. (14) as the accounting identity does not alter our analysis or critique. All Wan is doing is manipulating an identity. Second, even under the neoclassical assumptions, Wan's empirical measure of technical change is biased, as he uses national accounts data for the United States.[7] The only reason his estimate of the residual differs from that of Solow is, as we have seen, the use of a different base year, the choice of which Wan admits is arbitrary.

To conclude, the discussion above leads us to consider Wan's new approach as problematic and to question if it is in any way new. Wan starts off by writing the value-added accounting identity and he simply transforms it into an equivalent form. However, since one cannot infer anything about the rate of technical change solely from an identity, we must conclude that his method suffers from serious limitations.

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[6] We term them hypothetical because, of course, data for Eq. (14) are not readily available. In practice one would have to estimate the rental price of capital using the methodology developed by Hall and Jorgenson (1967). This is based on an infinite-horizon dynamic optimization model in which the rental price of capital is derived from the first-order conditions. The interpretation and measurement of the elements in the rental price formula are subjects of frequent confusion and controversy at both the theoretical and the empirical level (Mohr, 1986).

[7] In the case of China, Wan seems to use output at market prices, deflated by the national income deflator. The price of capital "is an arbitrary choice, which must be made in the absence of better alternatives" (Wan, 1995, p. 315). It is not clear from the discussion whether the Chinese data used are internally consistent, in other words, whether the accounting identity holds.

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