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Author(s): Werner Roeger
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Can Imperfect Competition Explain the Difference between Primal and Dual Productivity Measures? Estimates for U.S. Manufacturing

Werner Roeger

European Commission

It is well known that under the assumptions of constant returns to scale, perfect competition, and the absence of factor hoarding, primal and dual productivity measures should be highly correlated. The apparent lack of correlation is usually attributed to fixed factors of production. In this paper I propose an alternative explanation by relaxing the assumption of perfect competition. By controlling for the presence of a markup component, I demonstrate that both productivity measures are in fact highly correlated for U.S. manufacturing. The analysis also provides an alternative method of estimating a markup of prices over marginal cost that avoids certain difficulties inherent in some existing methods of estimation.

I. Introduction

It is well known that under certain assumptions total factor productivity (TFP) can be calculated either as the residual in the production function or, alternatively, as the residual of the dual cost function. With respect to the first measure, Solow (1957) has shown that the percentage change of TFP can be measured from observed data directly for a constant returns technology with the additional assumption of perfect competition. Analogously, under the same set of as-

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sumptions, the change of TFP can also be calculated using data on input and output prices (see, e.g., Hulten 1986). The first method especially has enjoyed great popularity and is widely used as a measure for technical progress. However, its use is accompanied by nagging doubts concerning the adequacy of this measure for real-world phenomena. It is often argued that the Solow residual is flawed with measurement error since it fails to distinguish between true shifts in the production function and cyclical changes in productivity due to varying degrees of factor utilization. The degree to which this is true, however, is very much disputed. Hall (1988) and Caballero and Lyons (1992) argue in favor of the unimportance of the factor utilization argument, whereas Abbot, Griliches, and Hausman (1989), Gordon (1992), and Basu (1993) attribute major importance to varying degrees of factor utilization. Also, Burnside, Eichenbaum, and Rebelo (1993) find that introducing labor hoarding in a "real business cycle" model reduces the ability of the Solow residual to account for aggregate fluctuations by about 50 percent. In this paper I want to contribute to this discussion by using information from both residuals in order to identify likely causes for measurement error in TFP. Under ideal conditions (i.e., when all assumptions—constant returns to scale, perfect competition, and the absence of labor hoarding or the underutilization of capital—are fulfilled and purely statistical measurement errors in the data are small), both TFP measures should be highly correlated. In fact, there is a rather low correlation. For example, Shapiro (1987) finds an R^2 of .13 from a regression of the Solow residual on its dual for total U.S. manufacturing, and he attributes this finding to the fixity of capital. In this paper it is argued instead that the lack of correlation should not be explained by the presence of fixed factors of production, but is likely to be the consequence of a positive markup of prices over marginal cost in U.S. industry.

To test this proposition, I carry Hall's insight concerning the decomposition of the Solow residual into a pure technology component and a markup component one step further by looking at the implication of a positive markup for the calculation of the dual productivity residual. My analysis goes beyond the method adopted by Shapiro (1987), who also uses both measures to test the factor utilization argument. He calculates both measures under the assumption of perfect competition and regresses the difference on a demand shock indicator. In contrast, I derive an expression for the difference of both indicators under the assumption of imperfect competition. Therefore, by testing for the presence of labor hoarding or underutilization of capital, I can control for the possible presence of imperfect competition. Moreover, I shall be able to estimate a markup of prices over marginal cost and shall argue that this approach is in some respects superior to the method suggested by Hall, since it does not require the use of instruments that are very hard to select. Since I want to demonstrate that even a simple variant of imperfect competition can help to reconcile price- and quantity-based productivity measures, I follow Hall and assume constant markups.[1]

The paper is organized as follows. First, I briefly present Hall's method and then provide a representation for the dual residual, in the case of a positive markup. This allows me to derive an expression for the difference between the primal and dual productivity measures under imperfect competition. In Section IV, an alternative interpretation for the difference between both productivity measures is given, based on labor hoarding and excess capacity. In Section V, empirical results for U.S. manufacturing are presented. The paper ends with some concluding remarks.

II. Hall's Approach

Hall looks at the implications of relaxing the condition that price equals marginal cost for the derivation of the Solow residual as a measure of total factor productivity. Allowing for more general price-cost margins leads Hall to the observation that the difference between the year-to-year growth rate of output and a weighted average of the factor inputs, based on the respective output shares, cannot be entirely attributed to autonomous technical change as in the case of perfect competition. If price exceeds marginal cost, the input shares per unit of output do not sum to one but are lower because of the existence of a markup factor. Hall further observes that the degree to which price exceeds marginal cost can be estimated from the Solow residual. More formally, consider a firm with a linear homogeneous production function $F(N_t, K_t)E_t$ for value added Y_t, where N_t and K_t are labor input and capital, respectively, and E_t is a shift variable to represent changes in productive efficiency. If the firm is operating

[1] Much recent work has concentrated on cyclical movements of markups. However, as Chatterjee and Cooper (1993) note, the evidence advanced so far does not convincingly refute the assumption of acyclical markups. Domowitz, Hubbard, and Petersen (1988), e.g., report some modest procyclical movements, whereas Rotemberg and Woodford (1991), among others, provide evidence in favor of countercyclical markups. As Ramey (1991) points out in the discussion of their paper, this result is likely to be the consequence of using Hall's very high average markup estimates in constructing an observable expression for the markup series. Ramey's own empirical analysis (which is restricted to total manufacturing) does not reject the hypothesis of acyclical markups. Given the weak empirical evidence in favor of pronounced cyclical markup fluctuations, indicated by these conflicting results, my simplifying assumption seems not too strongly at odds with the data.

under imperfect competition, Hall shows that the Solow residual (SR_t),[2]

$$SR_t = (\Delta y_t - \Delta k_t) - \alpha_t(\Delta n_t - \Delta k_t) = B(\Delta y_t - \Delta k_t) + (1 - B)\Delta e_t, \quad (1)$$

with $\alpha_t = W_tN_t/P_tY_t$, can be decomposed into a markup and a technology factor. The coefficient B is directly related to the markup of prices over marginal cost (μ) via the relationship $\mu = 1/(1 - B)$. However, estimation of B is difficult since $\Delta y_t - \Delta k_t$ and Δe_t are positively correlated under the null and alternative hypotheses. In order to estimate B, instruments must be found that are correlated with output but are neither a consequence nor a cause of technological innovations. Ideal candidates as instruments would be pure demand shocks. But Hall himself finds it difficult to detect instruments that are exogenous under all views of macroeconomic fluctuations and have a large enough influence on output such that the test is powerful. The instrumental variables used by Hall to reflect demand but not technology shocks for each sector are the rate of growth of military purchase of goods and services in real terms, the rate of increase of the world price of crude petroleum in dollars, and a dummy variable with the value of one when the president is a Democrat and zero when he is a Republican. This choice of instruments will be further discussed in Section V below.

III. A Test Based on Primal and Dual Productivity Measures

If one applies reasoning similar to that in the case of the primal technology residual, the price-based residual can also be decomposed into a pure technology component and a markup factor. To derive the dual residual under imperfect competition, I proceed by postulating a general cost function $C(\cdot)$ for a representative firm operating under constant returns to scale:

$$C(W_t, R_t, Y_t, E_t) = \frac{G(W_t, R_t)Y_t}{E_t}, \quad (2)$$

which corresponds to the linear homogeneous production function $F(\cdot)$ from above. The function $G(\cdot)$ is of course also homogeneous of the first degree. Marginal costs (MC_t) are given by

$$\frac{\partial C_t}{\partial Y_t} = MC_t = \frac{G(W_t, R_t)}{E_t}. \quad (3)$$

[2] I adopt the following convention: Δx_t is the log difference of the variable X_t.

Logarithmic differentiation of (3) yields

$$\Delta mc_t = \left[\frac{G_W W_t}{G(\cdot)}\right]\Delta w_t + \left[\frac{G_R R_t}{G(\cdot)}\right]\Delta r_t - \Delta e_t, \tag{4a}$$

where $G_W = \partial G/\partial W$ and $G_R = \partial G/\partial R$.

Using Shephard's lemma, we can simplify this further to

$$\Delta mc_t = \left[\frac{E_t N_t W_t}{Y_t G(\cdot)}\right]\Delta w_t + \left[\frac{E_t K_t R_t}{Y_t G(\cdot)}\right]\Delta r_t - \Delta e_t, \tag{4b}$$

because $G_W = N_t E_t / Y_t$ and $G_R = K_t E_t / Y_t$.

Using the cost function, we can write (4b) as

$$\Delta mc_t = \left[\frac{W_t N_t}{C(\cdot)}\right]\Delta w_t + \left[\frac{R_t K_t}{C(\cdot)}\right]\Delta r_t - \Delta e_t. \tag{4c}$$

The change in marginal cost is a weighted average of changes in input prices with respect to their relative cost shares, minus the effect of technological innovation. Since under constant returns to scale the cost shares sum to one, we can rewrite (4c) as

$$\Delta mc_t = \left[\frac{W_t N_t}{C(\cdot)}\right]\Delta w_t + \left[1 - \frac{W_t N_t}{C(\cdot)}\right]\Delta r_t - \Delta e_t. \tag{4d}$$

The relation between price and marginal cost is given by

$$(1 - B)P_t = MC_t = \frac{G(W_t, R_t)}{E_t}. \tag{5}$$

From (5), the difference between the change in price and a weighted average of changes in factor prices, the dual or price-based Solow residual can be defined as

$$\alpha_t \Delta w_t + (1 - \alpha_t)\Delta r_t - \Delta p_t = -B(\Delta p_t - \Delta r_t) + (1 - B)\Delta e_t. \tag{6}$$

As with the Solow residual, the weights for the factor prices are the wage share in output for wages and its complement for capital costs. The close correspondence between this expression for prices and factor costs with Hall's expression for output and factors of production is easy to see. The quantity residual can be decomposed into a technological innovation term and the rate of change of capital productivity multiplied by B; the dual residual can also be decomposed into a term representing technological innovations and the rate of change of output prices, minus the rate of change of capital costs also multiplied by B.

By denoting the left-hand side of equation (6) by SRP_t and using this equation to substitute for Δe_t in (1), we obtain the following expression suitable for estimation of B:

$$\mathrm{SR}_t - \mathrm{SRP}_t = B\Delta x_t + u_t, \tag{7}$$

with $\Delta x_t \equiv (\Delta y_t - \Delta k_t) + (\Delta p_t - \Delta r_t)$.

Under the maintained assumption that factors of production can be adjusted instantaneously and that all variables in (7) can be measured without error, the error term u_t—which is the difference of measurement errors from the two productivity terms SR_t and SRP_t—would be identically zero for all t, and a markup for each period could be calculated directly from equation (7). However, even under the assumption of instantaneous adjustment, this cannot be expected. One important source for a nonzero u_t is classical measurement errors. In discussing the statistical problems associated with the Solow residual, Prescott (1986) and Evans (1992) regard mismeasurement of labor input as the most serious problem. It is very well known that different data-collecting agencies provide different estimates for hours worked. For example, hours data constructed from household surveys deviate from data on the basis of establishment surveys, thus indicating the presence of a possible classical measurement error. They are usually regarded as generated by the methods used by the particular data-collecting agency and are regarded as independent from true hours. Let n_t^o be observed hours and ϵ_t^c a measurement error. Then we can write

$$n_t^o = n_t + \epsilon_t^c \quad \text{with}\, E\epsilon_t^c = 0, E(\epsilon_t^c n_t) = 0, \tag{8}$$

yielding a possibly heteroscedastic error term

$$u_t = -\alpha_t \epsilon_t^c, \quad \text{with}\, Eu_t = 0, \mathrm{var}(u_t) = \sigma_{ut}^2. \tag{9}$$

Since hours appear only on the left-hand side of equation (7), these measurement errors do not constitute a problem for my regressions. There may also exist purely statistical measurement errors for value added. Waldmann (1991) argues that procedures by the Bureau of Economic Analysis to estimate value added in nonmanufacturing industries—using either a direct deflation or an extrapolation method—can induce serious measurement errors. Since, in the case of value added, errors appear on both sides of the equation, this would inflict an upward bias on my markup estimates. In order to minimize measurement errors in value added, I therefore follow Waldmann's suggestion and restrict the empirical analysis to the manufacturing sector. Other typical measurement problems that arise from errors in attributing nominal changes in value added to changes in quantity and price are irrelevant since they will cancel each other.[3]

[3] Baily and Gordon (1988) stress that the potential for measurement error in real value added is much higher than for current dollar values, because price indices may miss quality improvements.

Also, the rental price of capital is subject to some measurement error. It is calculated on the basis of an ex post real rate of interest instead of the theoretically correct expected real rate. I assume that the expectational error and measurement errors are mutually uncorrelated; therefore, this error only adds additional noise to the regression without causing any bias for the markup estimates. Owing to simplifying assumptions concerning depreciation, capital stocks may also exhibit measurement errors, but they are usually regarded as negligible. It should also be pointed out that my procedure is robust with respect to one important measurement problem, namely compensated variations in work effort.[4] Measurement errors inflicted on both SR_t and SRP_t will exactly cancel in this case. To see this, let the percentage change of labor input in period t be decomposed into changes in hours (Δh_t) and changes in effort (Δf_t):

$$\Delta n_t = \Delta h_t + \Delta f_t. \tag{10}$$

Though we cannot observe n_t directly, we can still observe the total wage bill $W_t N_t$ and therefore the wage share (α_t). Now Hall's equation can be written in terms of observable variables as

$$\begin{aligned}(\Delta y_t - \Delta k_t) - \alpha_t(\Delta n_t - \Delta k_t) = B(\Delta y_t - \Delta k_t)& \\ + (1 - B)\Delta e_t + \alpha_t \Delta f_t,&\end{aligned} \tag{11}$$

where the unobservable variation in work effort appears as an additional variable on the right-hand side. Since it must be assumed that compensated effort Δf_t is procyclical, neglecting it inflicts an obvious upward bias on B in Hall's regressions.

In deriving an observable expression for the price-based Solow residual, note that W_t is the wage rate in terms of a unit of labor input N_t, and the observed wage rate, which we denote by W_t^o, is defined as

$$W_t^o = \frac{W_t N_t}{H_t}. \tag{12}$$

[4] The importance of this type of measurement problem is downplayed by Hall. He offers two main arguments. First, the piece wage rate would have had to move countercyclically in some episodes to reconcile the observed wage bill with relatively large fluctuations in effort (see Hall 1990). The magnitude of these calculated fluctuations is, however, a direct consequence of his assumption that there are no shocks to technology; i.e., the variation in the Solow residual is entirely explained by fluctuations in work effort. Second, the lack of comovement between real compensation per hour and labor productivity is in his view (see Hall 1991) further evidence that workers are not compensated on a current basis. However, this view has recently been challenged by Solon, Barsky, and Parker (1994), who attribute this phenomenon to composition bias in aggregate real wage series.

Therefore, we get

$$\Delta w_t - \Delta w_t^o = \Delta h_t - \Delta n_t = -\Delta f_t, \tag{13}$$

and we can express SRP_t as

$$\alpha_t \Delta w_t^o + (1 - \alpha_t)\Delta r_t - \Delta p_t = -B(\Delta p_t - \Delta r_t) + (1 - B)\Delta e_t + \alpha_t \Delta f_t. \tag{14}$$

Changes in compensated effort affect both productivity residuals in the same direction. Therefore, when (14) is subtracted from (11), the unobservable effort term cancels.

IV. Misspecification Analysis

Another reason for a nonzero u_t could be the presence of Keynesian demand effects due to labor hoarding over the business cycle, as argued by Shapiro (1987). He suspects the two residuals to be affected differently by the state of demand in this case. By using the two examples provided by Hall for both excess capacity and labor hoarding, one can indeed show this to be the case.

Example 1: Excess Capacity

Assume that a firm has capacity K and must hire λK workers in order to produce any output at all. In addition, for each additional unit of output it wants to produce, it must hire ϕ workers. For Y units of output, employment is $\lambda K + \phi Y$, and the firm's marginal cost is ϕW. In competitive equilibrium, $P = \phi W$ whenever $Y < K$, and $P = (\phi + \lambda) W$ whenever $Y = K$. For a period in which output is below capacity, labor's share will be

$$\alpha = \frac{WN}{PY} = \frac{W(\phi Y + \lambda K)}{\phi WY}. \tag{15}$$

Because the competitive firm operates with a loss when capacity is not fully utilized, $\alpha > 1$, but it will be exactly equal to one at full capacity. Hall shows that the (primal) Solow residual is not affected from changes in capacity utilization; that is,

$$\Delta y - \alpha \Delta n = 0 \tag{16}$$

irrespective of the state of demand. It is interesting to note that the same proposition is not true for the dual residual. In both regimes, the condition $\Delta p = \Delta w$ holds; therefore,

$$\alpha \Delta w - \Delta p \begin{cases} > 0 & \text{in the excess capacity regime } (\alpha > 1) \\ = 0 & \text{under full capacity } (\alpha = 1). \end{cases} \tag{17}$$

Consequently, the difference between the primal and dual residuals is cyclical in the presence of excess capacity.

Example 2: Labor Hoarding

Assume that the technology $Y = N$, but firms operate off their production function in recessions because, if output goes down by one unit, employment decreases by only ϕ units ($\phi < 1$). Therefore, in a recession, marginal cost pricing implies $P = \phi W$. In the non-labor-hoarding regime, $P = W$ holds. That the Solow residual is equal to zero when there is no labor hoarding follows immediately. Let Y^c be full capacity output and let ΔY^r be a negative demand shock. Then we can write the Solow residual as follows in a state of insufficient demand:

$$\frac{\Delta Y}{Y^c - \Delta Y^r} - \frac{W(Y^c - \phi \Delta Y^r)}{\phi W(Y^c - \Delta Y^r)} \frac{\phi \Delta Y}{Y - \phi \Delta Y^r} = 0. \quad (18)$$

Again, the Solow residual does not indicate technical change in the labor-hoarding regime. Contrary to the primal residual—because $\alpha \neq 1$ under labor hoarding—the dual residual indicates technical change when labor hoarding prevails; thus the difference between SR_t and SRP_t will be cyclical if labor hoarding is present in recessions.

In those cases the residual u_t in the regression equation (7) would just capture those demand effects. As suggested by Shapiro, this alternative can be tested directly by including a measure of demand in the regression above. The only difference between his and my regression is that I also control for the presence of imperfect competition.

V. Data and Results

The data are the same as those used in Hall (1988). Using the same data set allows me to compare markup estimates with those obtained by Hall more directly. Following the suggestion in Waldmann (1991), I restrict the analysis to the manufacturing sector of the U.S. economy on the two-digit level. The data cover the period 1953–84. The data on real gross value added (Y_t)[5] are taken from U.S. National Income and Product Accounts (NIPA); K_t is the net real capital stock from the Bureau of Economic Analysis, P_t is the implicit deflator with indirect

[5] Basu and Fernald (1993) argue in favor of using gross output as a measure of production, unless material input is roughly varied in fixed proportion with gross output. Norrbin (1993) finds this to be justified. He also reports results using both output measures and finds little difference for appropriately corrected markup estimates.

business taxes removed, N_t is hours of work of all employees taken from NIPA, and W_t is total compensation divided by N_t. I also follow Hall (see Hall and Jorgenson 1967) in constructing the rental price of capital. It should be noted that Hall's original method for estimating the markup does not require the use of capital costs and may therefore be more robust by allowing for cases in which capital is a true fixed factor of production. However, since I am testing my specification against the presence of demand effects (which cannot be done with Hall's method), I am in a position to test whether this restriction is violated by the data.

The results shown in table 1 are ordinary least squares estimates of equation (7). As indicated above, the error term can exhibit heteroscedasticity and serial correlation. Since the choice of the wrong variance model will in general lead to inconsistent estimates of standard errors, I apply White's (1980) procedure for the estimation of a consistent covariance matrix, which imposes little structure on the error process.

My regression results for the U.S. manufacturing sector show that imperfect competition explains more than 90 percent of the difference between the primal and dual productivity measures with generally significant markups. The generally excellent fit of these equations suggests that imperfect competition might be the cause of this discrepancy. In this respect, my results support Hall's initial claim that prices exceed marginal cost in U.S. manufacturing. Another interesting result concerns the magnitude of the markup ratio in my regressions as compared to the results obtained by Hall. My estimates suggest substantially lower markups.[6] This becomes evident by comparing columns 2 and 5 in table 1. When the average material input shares reported by Norrbin (1993) are used, the estimated markup ratios range from 1.05 (apparel) to 1.23 (tobacco and chemicals). My results are also more in line with cross-section studies such as, for example, the study by Bresnahan (1981) on the U.S. automobile industry. Poor instruments could be a main reason for a positive upward bias with Hall's method. As mentioned above, Hall's estimation method relies heavily on choosing instruments that are uncorrelated with the sectoral technology shocks. His two most important instruments, military purchases and the price of crude petroleum, may therefore not constitute pure demand shocks but—as can be easily

[6] In interpreting my estimates, one should also keep in mind that using value added instead of gross output will lead to an upward bias of the markup estimate. Let m be the material share in gross output. Then Hall has shown that unbiased markup estimates can be obtained by correcting the markup definition via the formula $\mu = 1/[1 - B(1 - m)]$, provided that value added and material inputs are roughly varied in fixed proportions.

TABLE 1

REGRESSION RESULTS FROM EQUATION (7), 1953–84

	B (1)	μ (2)	$\bar{R}^2$ (3)	Durbin-Watson (4)	μ_H* (5)
Construction	.31 (22.99)	1.44	.95	1.32	2.20
Durables	.31 (21.74)	1.45	.94	2.06	2.06
Nondurables	.32 (20.71)	1.48	.93	1.80	3.10
Food and kindred products	.33 (9.22)	1.50	.74	2.21	5.29
Tobacco	.64 (23.05)	2.75	.95	1.37	2.77
Textiles	.26 (12.59)	1.34	.84	2.19	2.58
Apparel and other textiles	.13 (5.99)	1.15	.54	3.00	.82
Lumber and wood products	.43 (23.46)	1.75	.95	1.93	1.80
Furniture	.22 (11.56)	1.28	.82	2.14	1.98
Paper and allied products	.36 (16.98)	1.57	.90	2.29	3.72
Printing and publishing	.29 (17.86)	1.40	.91	2.41	14.26
Chemicals	.53 (26.57)	2.11	.96	2.53	20.11
Rubber and plastic	.27 (10.70)	1.36	.79	2.43	1.50
Leather and leather products	.16 (4.80)	1.19	.42	2.76	2.10
Stone, clay, and glass products	.37 (20.09)	1.59	.93	1.84	2.54
Primary metal industries	.37 (12.10)	1.58	.82	2.33	2.17
Fabricated metal products	.25 (22.44)	1.33	.94	1.43	1.65
Machinery except electrical equipment	.29 (16.41)	1.41	.90	2.11	1.43
Electric and electronic equipment	.26 (11.36)	1.34	.81	1.98	3.09
Instruments and related products	.32 (12.68)	1.47	.84	2.50	1.40
Miscellaneous manufacturing industries	.38 (8.50)	1.62	.71	2.09	4.49
Electric, gas, and sanitary services	.68 (47.28)	3.14	.99	1.75	12.59
Motor vehicles and equipment	.52 (17.27)	2.06	.91	1.80	1.76
Other transportation equipment	.18 (3.31)	1.22	.27	1.33	.09

NOTE.—μ is the estimated markup ratio from regrssion (7), calculated as $1/(1 - B)$. t-statistics are in parentheses.
* μ_H is the markup estimate obtained with Hall's method.

TABLE 2

TESTING FOR DEMAND EFFECTS: EQUATION (19), 1953–84

	B	C	$\bar{R}^2$	Durbin-Watson
Construction	.31 (21.52)	−.07 (−.76)	.94	1.25
Durables	.31 (18.59)	.00 (.03)	.94	2.12
Nondurables	.33 (19.66)	−.07 (−.64)	.93	1.92
Food and kindred products	.35 (9.78)	−.41 (−2.00)	.76	2.38
Tobacco	.64 (23.09)	−.13 (−.79)	.95	1.44
Textiles	.26 (11.23)	−.02 (−.11)	.83	2.19
Apparel and other textiles	.14 (5.66)	−.11 (−.72)	.51	3.02
Lumber and wood products	.42 (20.41)	.23 (1.34)	.95	1.94
Furniture	.22 (10.62)	−.06 (−.43)	.81	2.23
Paper and allied products	.36 (15.00)	.11 (.72)	.90	2.30
Printing and publishing	.29 (16.88)	.00 (.01)	.91	2.50
Chemicals	.53 (24.77)	−.05 (−.34)	.96	2.61
Rubber and plastic	.27 (9.51)	−.11 (−.54)	.78	2.39
Leather and leather products	.17 (4.48)	−.10 (−.41)	.39	2.76
Stone, clay, and glass products	.39 (19.56)	−.23 (−1.57)	.93	2.09
Primary metal industries	.36 (9.44)	.14 (.47)	.81	2.36
Fabricated metal products	.24 (20.03)	.08 (.75)	.95	1.55
Machinery except electrical equipment	.31 (15.87)	−.25 (−1.99)	.90	1.89
Electric and electronic equipment	.25 (9.59)	.11 (.59)	.80	2.06
Instruments and related products	.31 (10.67)	.16 (.88)	.84	2.58
Miscellaneous manufacturing industries	.39 (7.96)	−.10 (−.30)	.69	2.14
Electric, gas, and sanitary services	.68 (48.26)	−.14 (−1.58)	.99	1.91
Motor vehicles and equipment	.55 (17.86)	−.88 (−2.33)	.92	2.28
Other transportation equipment	.23 (4.29)	−.81 (−2.36)	.37	1.39

NOTE.—*t*-statistics are in parentheses.

envisaged—may in fact be correlated with supply. It is especially hard to imagine that military purchases are entirely determined by political objectives and thus constitute a completely exogenous part of the U.S. government budget. The price of crude petroleum may be even more directly linked to the supply disturbance when one considers energy as an additional production factor for total output, as Bruno (1981) has shown, for example. Given the obvious difficulties of finding instruments that are exogenous, under both the null and various alternative hypotheses, an estimation method for μ that does not rely on the use of instruments has important advantages.

To check the robustness of my result against the "Keynesian" alternative, I also ask whether a demand indicator could better explain the difference between SR_t and SRP_t than the hypothesis of imperfect competition. Therefore, I add the growth rate of total gross national product as a proxy for changes of demand to equation (7) and estimate the following alternative specification:

$$SR_t - SRP_t = B\Delta x_t + C\Delta \text{gnp}_t + v_t. \qquad (19)$$

As indicated by the results presented in table 2, GNP growth adds almost nothing to the explanatory power of the equation and is insignificant for nearly all sectors, whereas the markup coefficient B remains significant and at roughly the same value for nearly all sectors of U.S. manufacturing.

As suggested by these results, the hypothesis of imperfect competition seems to be superior in explaining the difference between primal and dual productivity measures, when confronted with an explanation based on labor hoarding and excess capacity.

VI. Conclusions

In this paper, the hypothesis of imperfect competition was used to explain the apparent lack of correlation between primal and dual TFP measures in U.S. manufacturing. The empirical results presented above show the substantial explanatory power of this hypothesis. The hypothesis also clearly dominates alternative explanations as, for example, those based on labor hoarding and excess capacity. As a by-product of the analysis, I also provide an alternative method for estimating markup ratios that does not require the strong identifying assumptions as found in Hall's analysis.

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