Productivity, Private and Public Capital, and Real Wage in the United States 1948-1990

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Abstract

This paper examines the relationship between real wages in the United States and productivity. The measure of productivity includes the impact of public capital as well as private capital. Both neo-classical and Keynesian theories predict that real wages increase with increases in the capital stock and technical progress, and move inversely over business cycles. However, the question of whether real wages are cyclical or countercyclical has not been confirmed by empirical studies. These studies, however, ignore the impact of public capital on productivity. Using Cobb-Douglas production function estimates, this paper incorporates the impact of public capital on productivity and real wage. The results indicate that when the capital stock is controlled for, real wage is countercyclical, and validate diminishing returns to labor, positive returns to public capital and a procyclical effect of capacity utilization on real wage. Addressing stationarity concerns, estimates from the productivity equation establish a long-run relationship between productivity, measured as output per unit of capital, and employment to capital ratio, and the public capital to private capital ratio. Estimates from the real wage equation indicate that a long-run relationship exists between real wage and labor productivity and the public to private capital ratio.

Using the statistical estimates herein, if the public capital stock had remained at the historical 1948-1965 ratio, rather than declining, productivity would have been between 2.4 and 2.9 percentage points higher and real wages would have been between 2 to 2.8 percentage points higher, ceteris paribus. These projections translate into a potential increase in gnp per capita and a higher, rather than stagnating, standard of living.

Productivity, Private and Public Capital, and Real Wage
in the United States, 1948 - 1990

Introduction

Many articles involving research that attempts to provide both a theoretical and empirical understanding of the specification of aggregate real wage include, among other variables, the effect of business cycles and productivity. Whether the underlying theoretical model is based on the neo-classical view, or Keynesian, both predict that real wages increase with increases in the capital stock and technical progress, and move inversely over business cycles. For example, Otani (1978) states, "A typical growing economy is expected to have a positive trend growth in both real wages and output . . . [reflecting] increases in the capital stock and technical progress" (p. 301). As Bodkin has observed, "Rates of wage payments (real) have shown a pronounced upward trend for virtually all developed economies over the past century. An interesting issue, however, arises when one considers the shorter period of time implicit in the analysis of business fluctuations. When employment rises owing to a fuller utilization of productive capacity, do real rates of wage payments also increase or do they show a contracyclical movement?" [Bodkin, 1969, pp. 353-354].

This countercyclical relationship, assuming competition, is based on the concept that diminishing product occurs as employment increases, thus lowering real wages. Empirical studies do not unanimously confirm countercyclical real wage. Among the many, Neftci (1978), Sargent (1978), and Otani (1978) report countercyclical real wage movements, while Bils (1985) reports procyclical real wage movements, and Geary and Kennan (1982), and Kim and Loungani (1992) find evidence of neither. More recently, Sumner and Silver (1989) and Gamber and Joutz (1992) find that real wage movements vary over the business cycle, changing from procyclical (due to aggregate supply shocks) to countercyclical (due to aggregate demand shocks).

The direct relationship between real wage and productivity is based on the concept that, ceteris paribus, increases in the capital stock shift both the production function and demand for labor upward, increasing real wage. As Manning [1993], Minford [1983], and others have pointed out, (measures of productivity) "play a crucial role in accounting for the trend in real wages over time," [Manning, 1993, p. 98]. Although many of the empirical studies include a discussion of the relationship between real wage movements and changes in productivity reflected in changes in capital stock, the empirical models typically use a time trend designed to capture these effects. For example, Minford (1984) includes an exogenous labor productivity variable to address technological progress and productivity. However, after carefully explaining the slowdown in productivity growth that occurred in the U.K. during the 1970's, he uses a time trend as a proxy for the productivity variable. (This time trend turns out to be not statistically significant.) According to Nickell's (1984) review of Minford's work, he states, "it is clear that the Minford wage equation . . . contains nothing which could conceivably account for the natural upward movement in real wages which takes place over time (although not on a fixed trend!). This has the effect of inducing a spuriously large coefficient on the lagged dependent variable which then generates very large long run effects for the other regressors" (p. 951).

An important issue, then, is to determine how much real wage changes in response to both shifts in and movements along the demand for labor. It is obvious that there are problems with merely using a time trend to represent changes in productivity. Studies that do attempt to model productivity change usually report improved statistical results when the level of the capital stock is taken into account. For example, Canzoneri's [1977] research on the returns to labor and the cyclical behavior of real wages utilized the following neo-classical production function:

(1) $y_t = \beta_o + \beta_1 t + \beta_2 k_t + \beta_3 n_t$

(2) $y_t - k_t = \beta_4 + \beta_5 t + \beta_6 (n_t - k_t)$

(3) $w_t - p_t = \beta_7 + \beta_8 t + \beta_9 (n_t - k_t)$

Where:

y_t = log *of output*
k_t = log *of the capital stock*
n_t = log *of total labor hours*
p_t = log *of the price of output*
w_t = log *of the wage rate*

Equation (3) is a neo-classical demand curve for labor, specified in terms of labor hours-capital ratio used as an inverse measure of the marginal productivity of labor, and technological change (t). Utilizing Canadian data, Canzoneri's results indicate that "real wages are strongly counter-cyclical when the level of the capital stock is controlled for . . . (the statistical results) do not appear to be inconsistent with diminishing returns to labor" (pp. 20-21). Also, as discussed by Manning [1993], a term such as $(y_t - k_t)$ can be used in order to enter the effect of productivity into the wage equation.

Although these models measure productivity changes by including changes in the capital stock, this type of productivity change has been limited to private capital. Recent work by Aschauer [1989], Erenburg [1993a and 1993b], Munnell [1990], Lynde and Richmond [1992], etc., has shown that public capital stock, as well as private capital stock, is correlated with various measures of economic activity such as output, private investment and productivity growth. For example, Aschauer's work indicates that public capital is a key determinant of productivity growth. His empirical estimates show a strong positive relationship between output per unit of private capital and the public capital/private capital ratio. The coefficients on the labor-capital ratio and the public to private capital stock ratio are both positive and significant, with point estimates of .35 and .39 respectively. (Estimates without public capital reveal problems with serial correlation and unexpected signs and statistical insignificance.) Other areas of research have focused on the impact of public capital on costs of private production. Lynde and Richmond [1992] find that the marginal productivity of public capital is positive and suggest that public and private capital are complements in production. Nadiri and Mamuneas [1991] examine the relationship between public capital and costs of private production, finding, among other results, a statistically significant contribution of public capital to labor productivity.[1]

The recent research concerning the real effects of public capital discussed above is

[1]See also Shah (1992) who examines the relationship between public infrastructure and productivity in Mexico.

important because it indicates that if public capital is indeed a productive input, the decrease in U. S. public capital accumulation may be responsible, in part, for the productivity slowdown experienced in the U.S. over the last two decades. Figure I shows U.S. real wage in the U. S. from 1966 through 1990. Figure II shows the capacity utilization rate over the same time period. Figure III illustrates the public capital/private capital ratio, and Figure IV shows output per unit of capital. If real wage is a function of productivity, then, ceteris paribus, a decline (increase) in productivity will be associated with a decline (increase) in real wage.

Certainly, then, any attempt to determine the relationship between real wage and productivity should include the effect of public as well as private capital. This paper adds to the aggregate wage equation literature by empirically examining the relationship between real wage and productivity where productivity includes the effects of both private and public capital.

The Model

The following aggregate labor demand function, expressed in terms of real wage, incorporates the impact of productivity, ϕ_t, as follows:

(4) $(W/P)_t = g((W/P)_{t-1}, \phi_t)$

(5) $\phi_t = h(N_t, K_t, G_t)$

where W/P is real wage, N is aggregate employment of labor, K is private non-residential capital and G is public capital. Productivity is measured assuming a generalized Cobb-Douglas form for the production technology, competitive product and factor markets, and constant returns to scale across all factors of production, as indicated in the aggregate production function (6) and productivity of private capital (7) as follows:

(6) $Y = A(t) f(N, K, G)$

where Y is aggregate output, and A is technical change. Taking logs and rearranging yields:

(7) $y_t - k_t = a_t + b_n(n_t - k_t) + b_g(g_t - k_t)$ (where lower case indicates logs)

The following two equations specify real wage in terms of productivity, ϕ_t, defined as output per unit of capital, developed in (7), plus a time variable. Business cycle effects are added to (7) by adding the log of capacity utilization.

(8) $(w_t - p_t) = \alpha_o + \alpha_1(w_t - p_t)_{t-1} + \alpha_2(y_t - k_t) + e_{1,t}$
(9) $(y_t - k_t) = \mu_o + \mu_1 t + \mu_2(n_t - k_t) + \mu_3(g_t - k_t) + \mu_4 cu_t + e_{2,t}$

Combining (8) and (9) above yields:

(10) $(w_t - p_t) = \gamma_o + \gamma_1(w_t - p_t)_{t-1} + \gamma_2 t + \gamma_3(n_t - k_t) + \gamma_4(g_t - k_t) + \gamma_5 cu_t + \eta_t$
(11) $(y_t - k_t) = \mu_o + \mu_1 t + \mu_2(n_t - k_t) + \mu_3(g_t - k_t) + \mu_4 cu_t + \epsilon_t$

Real wage, specified as in Equation (10) above, is similar to Canzoneri's specification (see Equation 3 above). However, Equation (10) not only controls for the capital stock (Canzoneri's term $(n_t - k_t)$) allowing for the identification of the effects of diminishing returns to labor, but also allows for the identification of the separate effects of public capital (the term (g - k)). If public capital increases productivity, then there should be a direct relationship between real wage and the public capital term. Countercyclical wage movements are modelled by changes in the labor productivity variable. For simplicity, time is used as a proxy for technological change not captured in the capital stock.[2] Procyclical wage movements are modelled by changes in capital utilization. According to Merrick [1984], variation in capital utilization shifts the marginal product of labor. Entering capacity utilization as a separate variable, as in Aschauer [1989] and Erenburg [1993a], incorporates the effect of variation in capital stock utilization over the cycle. However, since changes in capacity utilization also change the utilization of the capital stock, another way to measure the effect of the business cycle is to adjust the capital stock for actual capital employed. This adjustment is made by multiplying the capital stock by the capacity utilization rate, thus indicating that the flow of capital services, and therefore the amount of capital stock per worker, changes over the business cycle. See, for example, Tatom [1991]. Equations (10a) and (11a) below incorporate the concept of the capital stock adjusted for capacity utilization, (ka).

$$(10a)\quad (w_t - p_t) = \gamma_o + \gamma_1 (w_t - p_t)_{t-1} + \gamma_2 t + \gamma_3 (n_t - ka_t) + \gamma_4 (g_t - ka_t) + \eta_t$$
$$(11a)\quad (y_t - ka_t) = \mu_o + \mu_1 t + \mu_2 (n_t - ka_t) + \mu_3 (g_t - ka_t) + \epsilon_t$$

Empirical Results

Tables I and Ia list the results of estimating equations (10) and (11), and (10a) and (11a), separately. The coefficients are of the expected sign and all are statistically significant (with the exception of the time variable in the real wage equation).

Focusing on the real wage equations, (10) and (10a), the data reveal a significant, inverse relationship between the labor productivity variable and real wage, with coefficients -.29

[2]The idea that technology is embodied in the capital stock is argued by Richard R. Nelson [1973], for example.

and -.32 respectively, indicating countercyclical wage movements. In addition, the point estimates of .225 and .22, respectively, indicate a direct relationship between public capital and real wage.

Focusing on the productivity equations, with capacity utilization entered as a separate variable as in equation (11), the data reveal a statistically significant, direct relationship between productivity, measured as output per unit of capital, and employment to capital ratio, and public capital to private capital ratio, with coefficients .44 and .50, respectively, validating diminishing returns to labor and positive returns to public capital. The coefficients indicate a significant, direct relationship between output, labor, public capital and the capacity utilization rate (with a point estimate of .006). When the productivity equation is estimated with the capital stock adjusted for capacity utilization, Equation (11a), the coefficients on labor and public capital are still positive and significant, but smaller in size.

The productivity and real wage estimates indicate diminishing returns to labor, counter-cyclical real wage, a procyclical effect of capacity utilization on real wage, positive returns to public capital, and through this positive productivity impact, a direct effect of public capital on real wage.

Tables II and IIa list the results of estimating equations (10) and (11), and (10a) and (11a), as a system, using non-linear, full information maximum likelihood measurement techniques. The coefficients in the real wage and productivity equations continue to support counter-cyclical movements in real wage, diminishing returns to labor, positive returns to public capital in both sets of equations. Specifically, the coefficients are significant, the same sign and approximate size.

Stationarity Tests and Long Run Relationships

In order to address the issue of spurious regression bias that arises when variables are not stationary, augmented Dickey-Fuller tests were used to detect the presence of a unit root in the levels of the variables used in the real wage and productivity equations with the capacity utilization adjusted capital stock. All variables are stationary or trend-stationary when first differenced. In order to examine long-run relationships between these variables, the equations with the capital stock adjusted for capacity utilization were re-estimated using the estimation procedure suggested by Stock and Watson [1989]. This method is applied when variables are integrated of higher order, including different orders. It includes significant leads and lags of the first-differences of both the dependent and independent variables in order to avoid the spurious regression bias that can occur when variables are nonstationary. The coefficients on the log-levels of the variables in the estimating equation indicate the presence of long-run relationships (or lack thereof) between the variables. Because the data are limited to annual observations, two leads and lags were used. The equations with capacity utilization entered as an independent variable were not estimated using this procedure because capacity utilization is of order I(0). The results are listed in Table III.

Focusing on the productivity equation with capital adjusted for capacity utilization, diminishing returns to labor are indicated with a statistically significant point estimate of

.24. Further, positive returns to public capital are supported with a point estimate of .29. The results are similar in size to those reported in Table IIa, and those reported by Aschauer [1989]. The first order autocorrelation term does not alter the size, sign or significance of the results.

Coefficients from estimation of the real wage equation indicate the presence of a long-run relationship between real wage, capital per worker and public capital when the capital stock is adjusted for capacity utilization. Focusing on the real-wage equation, the results indicate counter-cyclical real-wage movements with a point estimate of -.44. Further, a direct relationship between real wage and public capital is indicated with a significant point estimate of .28. These results are similar to the results listed in Tables Ia and IIa.[3]

Overall, estimates from the productivity equation establish a long-run relationship between productivity, measured as output per unit of capital, and employment to capital ratio, and the public capital to private capital ratio. Estimates from the real wage equation indicate that a long-run relationship exists between real wage and labor productivity and the public capital to private capital ratio.

Conclusions

Overall, these results establish a statistical relationship between public capital and productivity in the U.S., confirming the work of the previously cited authors, Aschauer, Erenburg, Munnell, Lynde and Richmond and Shaw, while addressing the problem of

[3]When the first-order correlation term is omitted, the coefficient on labor productivity is -1.05 and the coefficient on public capital to private capital ratio is .60.

spurious correlation. Also, these results add to the statistical evidence cited by Aschauer and Erenburg that not only does public capital directly affect productivity and private investment decisions [see also Erenburg, 1993b], but it also directly affects real wage through these productivity effects. The public policy implications are obvious. If the decline in public capital spending has contributed to the decline in the productivity in the U.S. over the last two decades, this paper indicates that this decline has also contributed to the lack of real wage growth, a prime component in the determination of a rising standard of living, over the same time period. Using the estimates from Tables II and III, if the public capital stock had remained at its historical 1948 - 1965 ratio, rather than declining, productivity would have been between 2.4 and 2.9 percentage points higher, and real wages would have been between 2 to 2.8 percentage points higher, ceteris paribus. These projections translate into a potential increase in gnp per capita and a higher, rather than stagnating, standard of living.

Fig. I: Real Compensation per Hour
1966 - 1990

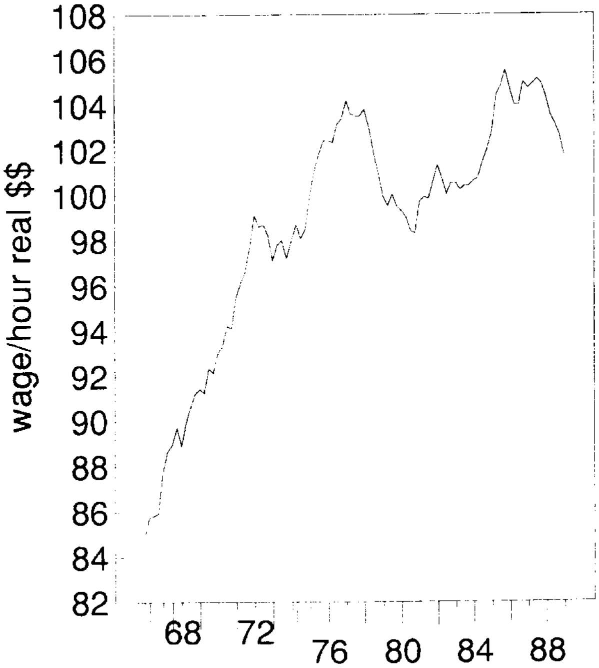

Fig. II: Capacity Utilization Rate
1966 - 1990

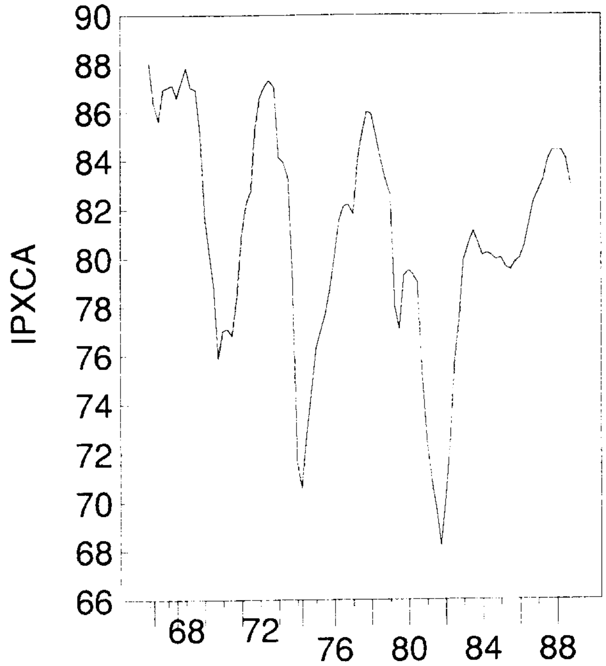

Fig. III: Public to Private K Stock
1966 - 1990

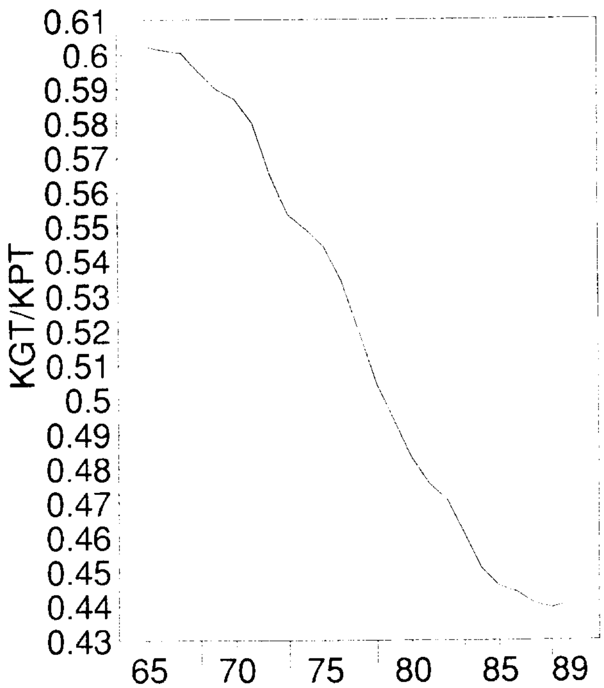

Fig. IV: Output Per Unit of Capital
1966 - 1990

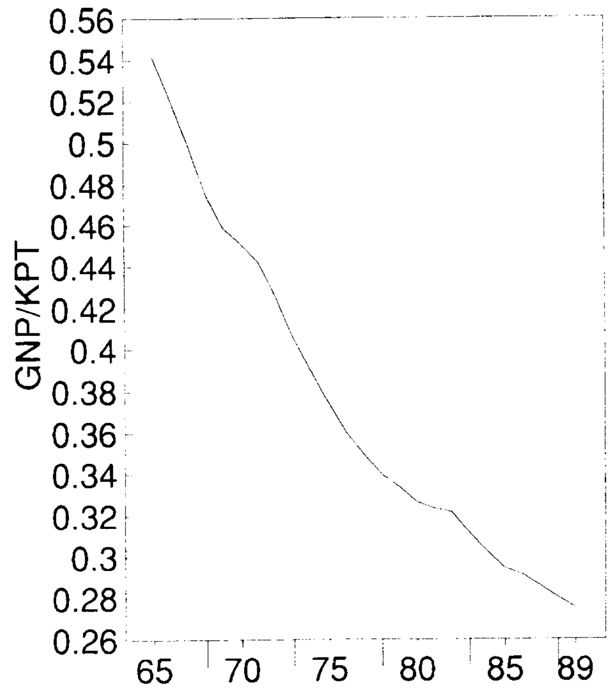

Table I

$$(10)\ (w_t - p_t) = \gamma_o + \gamma_1 (w_t - p_t)_{t-1} + \gamma_2 t + \gamma_3 (n_t - k_t) + \gamma_4 (g_t - k_t) + \gamma_5 cu_t + \eta_t$$ CRS= .998 DW = 1.91

$$(11)\ (y_t - k_t) = \mu_o + \mu_1 t + \mu_2 (n_t - k_t) + \mu_3 (g_t - k_t) + \mu_4 cu_t + \epsilon_t$$ CRS = .98 DW = 1.07

(11)		(10)	
(11) Constant	-4.97 (.39)	(10) Constant	.04* (.01)
Time	.57* (.12)	Real wage(-1)	.68* (.09)
(n - k)	.44* (.07)	Time	.0016 (.002)
(g - k)	.50* (.05)	(n - k)	-.29* (.125)
capacity utilization	.006* (.002)	(g - k)	.225* (.076)
		capacity utilization	.09* (.04)

Table Ia

Capital Stock Adjusted for Capacity Utilization

$$(10a)\ (w_t - p_t) = \gamma_o + \gamma_1 (w_{t-1} - p_{t-1}) + \gamma_2 t + \gamma_3 (n_t - ka_t) + \gamma_4 (g_t - ka_t) + \eta_t$$ CRS .997 DW 1.91

$$(11a)\ (y_t - ka_t) = \mu_o + \mu_1 t + \mu_2 (n_t - ka_t) + \mu_3 (g_t - ka_t) + \epsilon_t$$ CRS .96 DW .80

(11a)		(10a)	
(11a) Constant	-6.12* (.12)	(10a) Constant	.51* (.17)
Time	-.002* (.0008)	Real Wage	.67* (.09)
(n - ka)	.21* (.04)	(n - ka)	-.32* (.08)
(g - ka)	.24* (.03)	(g - ka)	.22* (.06)
		Time	.001 (.001)

(Standard Errors in Parentheses)

Stat. Sig.		
	.01	*
	.05	**
	.10	***

Table II

$$Eq.\ (10)\ (w_t - p_t) = \gamma_o + \gamma_1 (w_t - p_t)_{t-1} + \gamma_2 t + \gamma_3 (n_t - k_t) + \gamma_4 (g_t - k_t) + \gamma_5 cu_t + \eta_t$$

$$Eq.\ (11)\ (y_t - k_t) = \mu_o + \mu_1 t + \mu_2 (n_t - k_t) + \mu_3 (g_t - k_t) + \mu_4 cu_t + \epsilon_t$$

Eq. (10) CR2 .998; DW 1.90
Eq. (11) CR2 .98; DW 1.08

γ_o	=	.58	(.25)
γ_1	=	.67	(.09)
γ_2	=	.002	(.002)
γ_3	=	−.30	(.12)
γ_4	=	.23	(.07)
γ_5	=	.10	(.04)
μ_0	=	−4.97	(.37)
μ_1	=	.006	(.002)
μ_2	=	.57	(.11)
μ_3	=	.44	(.07)
μ_4	=	.09	(.04)

Table IIa

Capital Stock Adjusted for Capacity Utilization

$$Eq.\ (10a)\ (w_t - p_t) = \gamma_o + \gamma_1 (w_t - p_t)_{t-1} + \gamma_2 t + \gamma_3 (n_t - ka_t) + \gamma_4 (g_t - ka_t) + \eta_t$$

$$Eq.\ (11a)\ (y_t - ka_t) = \mu_o + \mu_1 t + \mu_2 (n_t - ka_t) + \mu_3 (g_t - ka_t) + \epsilon_t$$

Eq. (10a) CR2 .998 DW 1.90
Eq. (11a) CR2 .96 DW .79

γ_o	=	.52	(.17)
γ_1	=	.67	(.09)
γ_2	=	.0001	(.0009)
γ_3	=	−.32	(.08)
γ_4	=	.22	(.06)
μ_0	=	−6.12	(.11)
μ_1	=	−.002	(.0008)
μ_2	=	.21	(.04)
μ_3	=	.24	(.03)

(Standard Errors in Parentheses)

Stat. Sig.	.01	*
	.05	**
	.10	***

Table III

Capital Stock Adjusted for Capacity Utilization

Productivity Eq. (11)	CR2= .996 DW = .68
Constant	-6.07* (.23)
(n - ka)	.24* (.075)
(g - ka)	.29* (.07)
Δ (y - ka)(2)	-.25* (.09)
Δ (y - ka)(1)	-.61* (.09)
Δ (n - ka)(2)	-.18*** (.11)
Δ (g - ka)(2)	.25* (.10)
Δ (g - ka)(-1)	.26* (.06)
Δ rho	.91* (.04)

Real Wage Eq. (10)	CR2= .998 DW = 1.30
Constant	3.36* (.34)
(n - ka)	-.44* (.10)
(g - ka)	.28* (.09)
Δ real wage (2)	-.41* (.09)
Δ real wage (1)	-.66* (.08)
Δ (g - ka)(2)	-.04*** (.02)
Δ (g - ka)(1)	-.05*** (.03)
Δ rho	.95* (.004)

(Standard Errors in Parentheses)

Stat. Sig.		
	.01	*
	.05	**
	.10	***

LIST OF VARIABLES
(1948 - 1990)

Output	GNP (constant $$) Citibase
Employment	Civilian, Non-Institutionalized Total Employed Citibase
Public Capital Stock	Equipment and Structures, Federal, State & Local Government (constant $) U. S. Department of Commerce
Private Capital Stock	Private, Non-Residential Fixed Capital Stock (constant $) U.S. Department of Commerce
Capacity Utilization Rate	Citibase - Manufacturing
Real Wage	Real compensation per hour Wages and salaries plus employers' contributions for social insurance and private benefit plans. Also includes estimated wages, salaries and supplemental payments for the self-employed. Citibase

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