THE U.S. PRODUCTIVITY SLOWDOWN: A CASE OF STATISTICAL MYOPIA

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ABSTRACT

This paper identifies three major preriods: 1900-1929, 1929-1965, and 1965-1978. In contrast to the middle period, the extreme periods are characterized by rapid growth in private employment and hours worked; because growth in private product increases by less, measured labor productivity growth falls compared to the middle period. However this fall reflects a substantial substitution of quantity for quality in labor force growth: After private employment and hours are adjusted for age, sex, immigration, and education, no difference is observed among the average quality-adjusted labor productivity growth rates. Substantial variation in these growth rates remains within the 1929-1965 and 1965-1978 periods. Slow quality-adjusted labor productivity growth during 1929-1948 is just offset by unusually rapid growth during 1948-1965; these variations are attributed to the near cessation of investment during the Depression and World War II and subsequent recovery of the capital-labor ratio. Thus no substantial variations in total factor productivity growth or technical progress is found. Variations in productivity growth within 1965-1978 are explained by price-control induced biases in reported deflated output. Correction of these biases results in equal quality-adjusted labor productivity growth in 1965-1973 and 1973-1978. A substantial program of future research is proposed. A data appendix is included.

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The decline in American productivity has come to rival inflation as a major economic issue for public policy. Indeed something akin to panic has followed reports that labor productivity growth has declined from an average annual rate of 2.6 percent over 1948-1965 to 2.0 percent over 1965-1973 to 0.9 percent from 1973 to 1978.[1] This paper shows that the productivity panic is based upon statistical myopia and that a careful analysis within the perspective of the entire twentieth century discloses no substantial variation in what is variously described as growth in total factor productivity or technical progress.

The argument is made in two parts. First, three major subperiods are identified: 1900-1929, 1929-1965, and 1965-1978. It is noted first that the early and late periods are very similar to each other and are characterized, in comparison with the middle period, by rapid growth in labor force and a less than equal increase in growth in real output so that measured labor productivity falls. This picture changes dramatically when allowances are made for age, sex, education, and immigration to obtain a quality-adjusted labor force. The differential between the growth rates of output and quality adjusted hours worked is essentially identical across the three periods. Thus simple demographic adjustments eliminate any secular decline in technical progress.

The second part of the argument focuses on variations in productivity growth trends within the middle and later periods. It is shown that very slow growth in the capital-labor ratio from 1929 to 1948 accounts for very slow labor productivity growth during that sub-period as well as very rapid growth during 1948-1965. That is, the very rapid growth of 1948-1965 resulted from our poverty in 1948 and did not reflect desirable economic conditions. The more rapid productivity growth in 1965-1973 as compared to 1973-1978 is fully explicable by measurement error due to underreporting of price increases and hence overreporting of output increases due to Nixon's price control program. It is of particular interest that the oil price increases of 1973-1974 do not appear to have played a major role in slowing productivity growth.

The analysis was made possible by the development of a historical data base on productivity, labor force, and employment reported elsewhere.[2] Extracts of the relevant data are contained in a data appendix.

I. Analysis of Longer-Period Trends

The broad trends of the twentieth century are summarized in Table 1 for private employment (PE), average and total private hours worked (AHWP and THWP, respectively), gross private product (GPP), and private hourly and employee productivity (GPP/THWP and GPP/PE, respectively).[3] Darby (1982b) notes the periods 1900-1929 and 1965-1978 were characterized by rapid employment growth with immigration the relatively dominant factor in the early period and the baby-boom new entrants relatively more important in the recent period. The intermediate period 1929-1965 was marked by both tight limitation on immigration and a low rate of natural increase.[4] The three major periods were thus differentiated both by changes in immigration laws and by the post-war baby-boom's coming of age. Since the rate of decline in average hours worked was nearly constant, the changes in employment growth were the dominant factor determining variation in growth in total hours.

Each of the major periods has been divided roughly in half for later analysis.[5] At least for 1929-1965 and 1965-1978, the growth rate of private employment and total private hours is approximately the same in each subperiod as the mean for the respective major period. Thus each of these periods is homogeneous in terms of labor developments. The unevenness of immigration and estimated average-hours-worked growth in the first 29 years of the century makes the period 1900-1929 appear rather less homogeneous, but demographic adjustments discussed below eliminate most of the differences between the subperiods.

Focusing on the major periods in Table 1, we note that 1965-1978 is rather similar to 1900-1929 not only in employment and hours growth but also in output and productivity growth. Compared to 1929-1965, total hours growth is 1.0 to 1.2 percent higher in the earlier and later periods while GPP growth is only 0.4 to 0.5 percent higher. Thus hourly productivity growth is recorded as 0.5 to 0.7 percent lower in 1900-1929 and 1965-1978 as compared to 1929-1965. Correspondingly, growth in private output per person employed is 0.4 to 0.6 lower in the extreme periods than in the middle period. Two (possibly complementary) hypotheses provide possible explanations of the more rapid productivity growth in the middle period: (1) The hours and employment growth-rate declines in the middle period may be overstated due to failure to adjust for demographic changes, especially immigration and the baby boom. (2) Slower labor growth results in increased steady-state values of the capital-labor and output-labor ratios in the standard closed-economy neoclassical growth model. These hypotheses are examined in turn.

Demographics Hypothesis

Measures of private hours do not adjust for differences in human capital although the idea that an hour is an hour is as falacious as the idea that a 1962 dollar equals a 1982 dollar. Although elaborate adjustments such as Chinloy (1980) are precluded by limitations in the historical data, it is possible to make approximate adjustments for observed differences in productivity due to age, sex, education, and immigrant status.

Let us first consider the adjustment for the age-sex composition of the labor force. The private labor force estimates are divided into individual cells by sex and "young" (Y, under 25) or "old" (O, over 24). Standardizing on males over 24 and taking young males, young females, and old females as less productive because of differences in human capital, we compute age-sex adjusted private employment as

$$(1)\quad APE = PE_{MO} + \alpha_1 PE_{MY} + \alpha_2 PE_{FY} + \alpha_3 PE_{FO}$$

where the subscripts M and F indicate sex. The α's are chosen to reflect differences in average hourly earnings. Using data in Denison (1979, p. 33), this suggests α_1 of 0.53 to 0.50, α_2 of 0.43 to 0.41, and α_3 of 0.56 to 0.57.[6] We use 0.515, 0.42, and 0.565 as α_1, α_2, and α_3, respectively.

New immigrants to the United States on average earn substantially less than native-born Americans.[7] In part this reflects permanent differences in human capital endowments, but much of the difference is eliminated over time as the immigrants become acculturated. Since immigration is most important in the earlier period, Francine Blau's (1980) estimates based on 1909 data are used to adjust the foreign-born to native-born equivalents by the following formulas:[8]

$$(2)\quad PE_{Ma} = PE_{MNa} + (1.01076)^{Z_M}(0.753)PE_{MIa}$$

$$(3)\quad PE_{Fa} = PE_{FNa} + (1.01177)^{Z_F}(0.891)PE_{FIa}$$

where PE_{sIa} and PE_{sNa} are the (unadjusted) private employment of foreign born (I) and native-born (N) individuals of sex s and age-group a and where Z_s is the average years since entry of foreign-born workers of sex s.[9] The average years since entry was estimated according to the recursive formula

$$(4)\quad Z_s = (0.5)\frac{I_s}{P_s} + (Z_{s,-1} + k_s)\left(1 - \frac{I_s}{P_s}\right)$$

where I_s is the inflow of (sex s) immigrants over the preceding year, P_s is the corresponding foreign-born population, and k_s is a number between 0 and 1 to allow for disproportionate frequency of death and retirement among the less recent foreign-born. This formula says that the (mid-year) average years since entry is a weighted average — weights I_s/P_s and $1 - (I_s/P_s)$ — of 0.5 year for those arriving in the last twelve months and $Z_{s,-1} + k_s$ for those previously arrived and remaining in the labor force. Benchmarks for 1909 and 1970 were computed from the Immigration Commission data for 1909 and from 1970 Census data.[10] These benchmarks implied $k_M \simeq k_F \simeq 0.603$. The estimated values of Z_s are reported in the data appendix. Since the adjustments for years since migration of the foreign-born were made before the adjustment for age and sex described in equation (1), the variable APE is in fact adjusted for all these factors.

The final demographic factor believed to be important in determining the human capital content of the labor force is education. It is assumed that human capital is increased by 7 percent per year of education,[11] so that quality-adjusted private employment is

$$(5)\quad QAPE = (1.07)^E APE$$

The education variable E is measured by the median school years completed by those 25 years and over.[12]

Table 2 indicates the relative importance of the various demographic factors across the period by breaking the difference between unadjusted and quality-adjusted private-employment growth rates into age-sex, immigration, and education components.[13] Table 3 displays the differential effects in the three major periods by subtracting the average 1900-1978 value of each adjustment from the value of the adjustment for the period. For example, failure to adjust for age and sex in the productivity measures in Table 1 resulted in understating 1965-1978 productivity growth by -0.32 - (-0.01) = -0.31 percent per annum relative to 1929-1965. Overall, the productivity growth differential from 1929-1965 was overstated by 0.35 - (-0.27) = 0.62 percent per annum for 1900-1929 and by 0.35 - (-0.37) = 0.72 for 1965-1978.

Table 4 illustrates that after private employment is adjusted for these demographic factors, both the hourly and employee productivity measures show no significant variation across the major periods. In particular there is no indication of a secular productivity slowdown in 1965-1978 versus 1929-1965 or indeed the entire twentieth century. Furthermore, as noted above, we have used the hours measure most favorable to finding such a slowdown; the data on average private hours paid in fact decelerate in 1965-1978 which would imply a small (0.3 percent per annum) increase in hourly productivity growth.[14]

Capital-Deepening Hypothesis

Given the just-demonstrated ability of demographic adjustments to explain the measured secular variations in productivity growth, it smacks of pedantic digression to spend any time on the capital-deepening hypothesis -- particularly so because the latter will prove at odds with the data. Nonetheless a little consideration is due this hypothesis since its failure suggests interesting areas for future research.

The capital-deepening argument can be expressed in terms of the simple neoclassical growth model. Suppose that investment ($\dot{k}$) is determined by saving to be a constant fraction σ of output y:

$$(6) \quad \dot{k} = \sigma y$$

Suppose that output is determined by the linear homogeneous production function

(7) $y = f(k,\ell)$

where labor is measured in efficiency units so that the given constant growth rate of labor $\dot{\ell}/\ell$ is the sum of the growth rates of total hours and of the average quality of those hours.[15] It is well known that in steady-state equilibrium the growth rates of output and capital equal $\dot{\ell}/\ell$ with fixed ratios k/ℓ and y/ℓ.[16]

The capital-deepening argument runs as follows: The growth rate of labor in efficiency units (i.e., quality-adjusted) was about 0.4 percent per annum lower from 1929-1965 than before or after. The lower line of Figure 1 illustrates such a protracted slowdown in labor growth. During this intermediate period, the steady-state values of the k/ℓ and hence y/ℓ ratios will rise yielding the jump in steady-state output y_s at 1929 and corresponding fall at 1965. Figure 2 illustrates the predicted effect on actual output assuming that we were initially in steady-state equilibrium. In the middle period the actual growth rate of output is reduced by the slower steady-state growth rate of labor, but this is partially offset by the transitional effect of moving up to the higher ratio of y/ℓ. Thus the growth rate of productivity would be increased in the middle period as compared to the earlier period. A transitional effect would be operating in the opposite direction to reduce productivity growth in the post-1965 period.

Despite its elegance, I believe that the capital-deepening hypothesis is not a satisfactory explanation for the productivity trends at issue. Besides the fact that there are no unexplained secular increases in quality-adjusted productivity growth during 1929-1965, there is no evidence of an increase in the ratio of capital to output. In fact, over this period GPP grew at an average rate of 3.0% while corporate capital input as measured by Christensen and Jorgenson (1978, p. 35) grew by only 2.2%. As we shall see in Section II, there are reasons to suspect that this may be an underestimate of capital growth, but capital deepening still seems absent from the period.

An intriguing hypothesis for future research would be that the United States should not be viewed as a closed economy, as in the previous neoclassical growth analysis, but rather as a part of a world capital market. Conditions of saving and labor growth in this larger market would then control the evolution of the capital-labor ratio in America largely independently of fluctuations in domestic labor growth. Unfortunately, examination of international data must be left to the future.

Conclusions on Longer-Period Trends

Changes in immigration laws and the entry of the baby-boom divide the twentieth century into three major periods: before 1929, 1929-1965, and after 1965. From the point of view of growth in employment and hours, each major period seems reasonably consistent, but the middle period is characterized by considerably lower growth than either of the exterior periods. Since the growth rate of gross private product declines by less than the decline in hours growth in the middle period, measured productivity growth rises. Such a pattern is consistent with the implications of the neoclassical growth model, but no evidence of the corresponding sharp increase in the capital input is found. In contrast, it was shown that the demographic factors of age, sex, immigration, and education explain all of the measured secular variation in hourly productivity growth.[17] Thus, it appears that there is no substantial variation in trend private productivity growth over the twentieth century to be explained by variations in regulation growth, oil prices, the failure of American management, labor, or any of the other popular whipping boys. So far as broad trends go, the U.S. productivity slowdown appears to be a case of statistical myopia.

Demographic adjustments also appear to explain observed variations in private employee productivity growth within the period 1900-1929. The hourly productivity growth measure shows some residual variation (1.43% for 1900-1916 versus 1.96% for 1916-1929), but this appears to be related to anomolous growth in average hours. It is left for economic historians to unravel whether the hourly productivity measure reflects a real phenomenon or simply measurement error.

Much more substantial variations in hourly and employee productivity growth are reported in Table 4 within the periods 1929-1965 and 1965-1978. For example, quality-adjusted hourly productivity growth is reported as 1.0, 2.1, 2.0, and 0.9 percent per annum for 1929-1948, 1948-1965, 1965-1973, and 1973-1978, respectively. It is the task of Section II to explain this residual variaton.

II. Analysis of Intra-Period Variations

Section I argues that the quality-adjusted hourly productivity growth rate has had a constant secular value of 1.60 percent per annum throughout the twentieth century. Then how are we to explain the fact that this growth rate exceeded 2.0 percent per annum from 1948-1973 and was only 0.9 percent from 1973-1978? In this section it is first shown that the rapid 1948-1965 growth is explained by the recovery of the capital-labor ratio from its abnormally low level at the end of World War II and the Great Depression. That is, the rapid (slow) growth in labor productivity during 1948-1965 (1929-1948) is due to abnormal movements in the capital stock relative to labor and output and therfore is not reflected in total factor productivity growth or technical progress. Next it is demonstrated that the reported variations within the 1965-1978 appear to be the result of biases in measured output due to evasion of the 1971-1974 price controls. Correction of these biases eliminates any tendency for productivity growth to slow in 1973-1978 or to be above 1.6 percent per annum in 1965-1973.

The 1929-1965 Period

The slow growth in 1929-1948 and rapid catch-up growth in 1948-1965 is attributed here to the very low ratio of investment to output during the Great Depression and World War II. The idea is that in 1948 we were quite poor in the sense of a low capital-labor ratio and it took until around 1965 to recover to the steady-state capital-labor and output-labor ratios as illustrated in Figure 3.

An implication of the approximately equal quality-adjusted hourly productivity growth rates for 1900-1929, 1929-1965, and 1965-1978 is that the output-labor ratio is approximately the same in 1900, 1929, 1965, and 1978 after allowing for a constant rate of labor-augmenting technical progress.[18] Therefore, if capital growth explains the observed variation of output growth within the period, it follows that there was no significant intra-period variation in technical progress (total factor productivity growth).

A simple and usually serviceable characterization of the aggregate production function is the Cobb-Douglas form

$$(8) \quad y = e^{\tau t} k^{\beta} \ell^{(1-\beta)}$$

where τ is the rate of total factor productivity growth and ℓ is now <u>measured</u> (quality-adjusted) labor input. This can equivalently be written in logarithmic form as

$$(9) \quad \log y = \beta \log k + (1-\beta)\log(\ell e^{\gamma t})$$

where $\gamma \equiv \tau/(1-\beta)$ is the constant rate of labor-augmenting technical progress. Subtracting log ℓ from both sides of equation (9) and using Γ for the continuously compounded growth rate operator, we have

$$(10) \quad \Gamma(y/\ell) = \gamma + \beta[\Gamma k - (\Gamma\ell+\gamma)]$$

That is, the growth rate of labor productivity equals the rate of technical progress plus the product of capital's share and the difference between the capital and the adjusted labor growth rates.

The capital growth rate has been estimated as about 0.6 and 4.0 percent per annum for 1929-1948 and 1948-1965, respectively.[19] Equation (10) is used to predict the observed quality-adjusted labor productivity growth rate for a capital share of 1/4 as well as alternative value of 0.2 and 0.3. Table 5 reports the results which indicate that the actual and predicted growth ratio of quality-adjusted hourly and employee productivity correspond quite closely for 1929-1948. Thus the near cessation of investment during the Depression and World War II nicely explains the observed slowdown in productivity growth. Since the output-labor ratio has already been shown to return to its trend value by 1965, the solution seems to be complete.

Unfortunately, the second line of each part of Table 5 indicates that the predicted productivity growth falls short of actual growth by 0.2 or 0.3 percent per annum. It may be that this unexplained growth reflects a real temporary increase in technological progress that offsets an unusual fall in the capital-output ratio of some 24 percent over 1929-1965,[20] but a simpler and economic explanation is also possible. Quite possibly the fault lies in the capital data themselves: The quantum leap in tax rates during World War II provides an incentive to write off as current expense as much capital formation as possible; thus gross investment and capital growth could be systematically understated in the postwar period.[21] Suppose that a consistent data series would in fact show no decline in the capital-output ratio. This would imply that the true capital growth rate over 1948-1965 is 5.6 percent per annum.[22] In order for this to be the case, firms would have had to alter their accounting practices so that reported net investment was reduced relative to earlier practices by almost 24 percent. Given the large incentives, this magnitude does not appear unreasonable, but further research is clearly indicated.[23] In any case, the lower halves of each part of Table 5 indicates that a rather smaller capital growth rate would be sufficient to eliminate any apparent 1948-1965 rise in total factor productivity growth.

In summary, measured capital growth variations can explain all of the 1929-1948 slowdown in quality-adjusted labor productivity growth and a large part of the 1948-1965 increase in that growth relative to trend. The remaining 0.2 to 0.3 percent excess growth in 1948-1965 can be attributed either to an unexplained temporary increase in total factor productivity growth or to changes in net investment reporting in response to increased income taxes.

The 1965-1978 Period

It is not widely recognized that the main problem with productivity growth in 1973-1978 is concentrated in the seven quarters 1973 II through 1974 IV:

> The productivity decline in 1973-74 was particularly striking. Labor productivity in the nonfarm business sector fell in every quarter from the second quarter of 1973 to the fourth quarter of 1974, dropping a total of 4.2 percent in a 7-quarter period. On the basis of the usual relationship between fluctuations in productivity and fluctuations in output, no more than 1 percentage point of that decline could be attributed to the sharp recession during the period. The additional drop of 3.2 percentage points accounts for much of the difference between the expected 2 percent annual growth rate between 1973 and 1977 and the 0.9 percent rate that actually occurred.[24]

This section will demonstrate not only that the progressive relaxation and ultimate removal of general price controls during 1973-1974 can fully account for this anomolous excess productivity decline of 3.2 percent but also that the imposition of these controls during 1971 II through 1973 I can account for the peculiarly rapid productivity growth observed during those quarters.[25] This rapid productivity growth permits us to reject the popular oil-price hypothesis in favor of the price control hypothesis.

Before examining the evidence, it is useful to sketch these two competing hypotheses: The oil-price hypothesis as developed by such authors as Rasche and Tatom (1977, 1981) asserts that higher oil prices will significantly lower the equilibrium level of output consistent with a given level of labor and capital and will further induce a fall over time in the level of capital. The price-control hypothesis as developed in Darby (1976a, 1976b) asserts that measured real output was progressively overstated (and price understated) from their imposition in 1971 III through 1973 I and that this overstatement was progressively eliminated under Phase III and decontrol (1973 II-1974 III). Sung Hee Jwa (1982) has extended Darby's basic model by a formal analysis of firm and industry equilibrium. Darby (1982a) examines the oil-price and price-control hypotheses in detail using both U.S. and international data and finds that the preponderance of evidence supports the price-control hypothesis. This evidence will be supplemented below by directly estimating a productivity growth equation. Additional empirical evidence is presented in Appendix A.

First we wish to test whether oil price, price controls, or both had a significant influence on productivity growth other than via any temporary effects causing unemployment and employment to differ from their steady-state values. Standard productivity equations have deflated values on both sides inducing spurious correlation if the price control hypothesis is true. Fortunately, a simple dynamic Okun's Law extended by other current and leading labor-market indicators provides very respectable explanatory power without potential spurious correlation. The basic equation used corresponds in right-hand variables to equation (5) in Darby (1982a):

$$\text{(11)}\quad \Delta\log\,(y/\ell)_t = a_1 + a_2 TS_t + a_3\Delta u_t + a_4\Delta LR_t + a_5\Delta\log\,E_t + a_6\Delta\log\,E_{t-1} + \varepsilon_t$$

where $(y/\ell)_t$ is the private-hours-paid definition of labor productivity,[26] TS_t is a time shift dummy equal to 0 before 1965 and 1 otherwise,[27] u_t is the total unemployment rate, LR_t is the layoff rate, and E_t is employment in manufacturing, mining, and construction. Note that the cyclical indicators used in this equation are all based on counts of individuals and so not subject to possible reporting biases (as are deflated series) under price controls. The estimated equation for 1949 I-1980 IV is:[28]

$$(12)\quad \Delta\log (y/\ell)_t = \underset{(7.55)}{0.0069} - \underset{(-1.73)}{0.0022}\, TS_t - \underset{(-3.19)}{0.010}\, \Delta u_t$$

$$- \underset{(-0.37)}{0.001}\, \Delta LR_t + \underset{(0.28)}{0.026}\, \Delta\log E_t - \underset{(-4.04)}{0.308}\, \Delta\log E_{t-1}$$

$$S.E.E. = 0.0071, \qquad \bar{R}^2 = 0.30, \qquad D\text{-}W = 2.02$$

This equation does reasonably well at explaining quarterly fluctuations in productivity growth, although only the current change in unemployment and the lagged growth rate of employment are significant among the cyclical indicators.

To test the price control hypothesis, a simple quantitaitve variable was formed: CD_t grows linearly from 0 in 1971 II to 1 in 1973 I and then falls linearly back to 0 in 1974 IV. The deflated dollar price of a barrel of Venezuelan oil was used for the oil price P_t. The following general equation was estimated with up to a one year adjustment lag permitted for oil prices to take effect:

$$(13)\quad \Delta\log\,(y/\ell)_t = a_1 + a_2TS_t + a_3\Delta u_t + a_4\Delta LR_t + a_5\Delta\log\,E_t$$

$$+ a_6\Delta\log\,E_{t-1} + a_7\Delta CD_t + \sum_{i=0}^{3} a_{8+i}\Delta\log\,P_{t-1} + \varepsilon_t$$

Table 6 reports the results of various alternative hypothesis tests that might be conducted. Line 1 pertains to equation (13) as stated while all the other lines involve various zero constraints on $a_7,\ldots,a_{11}$.[29] We see that whenever the price-control variable is included it is significant at the 5 percent level or better. The oil variables, in contrast, are never significant except for line 5 in which, with both the price-control variable and lagged growth in oil prices forced out, current oil-price growth is significant at the 10 percent level on a one-tailed test. I conclude that oil-price changes had no significant effect on productivity growth. Note particularly that a major increase in real oil prices occurred between 1979 I and 1980 I, but no direct effect was detectable.

The final form of the regression is

$$(14)\quad \Delta\log(y/\ell)_t = \underset{(7.88)}{0.0069} - \underset{(-1.81)}{0.0022}\,TS_t - \underset{(-3.23)}{0.010}\,\Delta u_t - \underset{(-0.24)}{0.000}\,\Delta LR_t$$

$$+ \underset{(0.20)}{0.018}\,\Delta\log\,E_t - \underset{(-4.15)}{0.304}\,\Delta\log\,E_{t-1} + \underset{(3.41)}{0.04397}\,\Delta CD_t$$

$$S.E.E. = 0.0068, \qquad \bar{R}^2 = 0.36, \qquad D\text{-}W = 2.14$$

Consider the implications of this equation for the level of productivity in the year 1973. The average value of CD_t in 1973 is 0.7857 which, when multiplied by 0.043997, implies that the logarithm of labor productivity in 1973 was overstated by 0.0343.[30] This means that the 1965-1973 growth rates of private labor productivity are overstated by 3.43/8 = 0.43 percent per annum and correspondingly that the 1973-1978 growth rates are understated by 3.43/5 = 0.69 percent per annum. Table 7 shows that applying this correction to the quality-adjusted productivity growth rates of Section I completely eliminates any evidence of a 1973-1978 productivity slowdown. Instead the picture is one of remarkably stable productivity growth over the period 1965-1978 after accounting for the 1973 measurement biases.

It is of course true that price controls could have had real effects, but these effects should have operated by changing unemployment and employment. The estimated coefficient of ΔCD captures some additional impact which must either measure output overstatement or some shift in the relationship of output to labor inputs for a reason yet to be proposed in the literature. For any yet skeptical reader, additional discussion and evidence is contained in Appendix A.

III. Conclusions and Areas for Future Research

The results of this study can be clearly summarized by the use of two figures. Figure 4 illustrates the logarithm of hourly productivity measured in the standard way by GPP/THWP. It is difficult if not impossible to discern any overall trend although 1900-1929 and 1929-1948 might be identified as periods of slow growth followed by rapid growth during 1948-1965 and then slowing growth over 1965-1973 and 1973-1978. The logarithm of quality-adjusted hourly productivity (GPP/QATHWP) is plotted in Figure 5. Here a constant trend line dominates the data except during the Depression-Korean War era of slow investment and subsequent rapid recovery. With demographic factors accounted for, the anomolous productivity gains in 1972 and 1973 (which we attribute to measurement biases) stick out like the proverbial sore thumb.

The major conclusion to be drawn is that there have been no substantial variations in trend growth rates of private labor productivity since 1900 if reasonable adjustments are made for the effects of demographic trends on the average quality of labor. Even if one were to ignore the effects of demographic shifts, the measured growth rates of productivity, total private hours, and private employment have essentially the same values in 1900-1929 as in 1965-1978 so that panic may be premature.

The slow labor productivity growth in 1929-1948 can be explained by the near cessation of capital formation, but measured increases in capital growth in 1948-1965 are too small to fully account for the catch-up of labor productivity. Further research is required to determine whether this is due to problems in the measurement of capital or to other yet undiscovered factors. The slowdown in productivity growth within the period 1965-1978 can be readily explained by measurement biases induced by evasion of price controls. Increased oil prices do not play a significant role.

Taken as a whole, the evidence does not support the view that there has been a substantial, inexplicable decline in total factor productivity growth since 1965 and especially since 1973. Instead the evidence presented here indicates that there has been a surprisingly stable growth rate of total factor productivity throughout the twentieth century. Only in 1948-1965 is there any evidence of a substantial (0.2 to 0.3 percent per annum) temporary increase in total factor productivity growth and there are good economic reasons to suspect that this may be an artifact of tax-induced changes in accounting procedures.

A considerable program for future research which has been noted in previous sections can be briefly summarized here: (1) An interesting issue for economic historians is whether the intra-period inconsistency between hourly and employee productivity growth for 1900-1929 reflects a real phenomenon or indicates a measurement problem in the data on average hours worked. (2) Certainly improvements can be made to the demographic adjustments reported here. Doubtless others will test these results by doing so. (3) The failure of the closed-economy neoclassical growth model suggests an (industrialized) world linked by capital flows which are quite responsive in the long-run. So like analysis of other economies could similarly explain their postwar labor productivity recoveries and slowdowns. It further suggests investment incentives may be more effective than saving incentives as means of increasing domestic capital stock. (4) In light of the discrepancy between full recovery in the output-labor ratio and incomplete recovery in the capital-labor ratio, a reexamination of the consistency of existing estimates of net investment and the capital stock is in order. (5) The potential importance of price-control induced biases in deflated (and deflator) data during the 1971-1974 period is once again demonstrated. Further evidence is called for on this issue, but the time has come to reexamine various claims for effects of oil-price and other variables which may serve as a proxy for these reporting biases.

One must conclude with a warning note: The fact that factors such as regulation, governmental size, oil prices, management practices, educational quality, moral fiber, and the like have not been required to fully explain twentieth century variations in labor productivity does not imply that they have been unimportant. Any or all of them may have been quite important in determining the trend value of total factor productivity growth. Nonetheless in the aggregate their impact has caused quality-adjusted total factor productivity growth to evolve as if following a random walk with constant drift and small variance. For this type of process the average growth rate of total factor productivity growth converges over considerable periods to the constant drift.

APPENDIX A

ADDITIONAL DISCUSSION AND EVIDENCE ON THE PRICE-CONTROL HYPOTHESIS

This Appendix provides discussion and evidence on the price-control hypothesis supplementary to that contained in Darby (1976a, 1976b, 1982a) and in the main text of this paper.

There are three popular models of the effects of Nixon's Economic Stabilization Program (ESP): The first, used as the basic economic support for the program, argued that sticky expectations and nominal contracts would delay adjustment to a new lower, noninflationary equilibrium. The ESP, the argument goes, would accelerate the adjustment process and minimize the transitional increase in unemployment. The second view, associated with Barro and Grossman (1974) and Evans (1980), argues that general price controls reduce real output and inflation by inducing increased consumption of leisure. The third view, which I have proposed, argues that the ESP was largely window-dressing and was easily evaded by minor covert quality depreciation both in physical products and services and in the terms on which they were sold.

Needless to say, these views are not mutually exclusive. For example, the ESP most probably reduced the unemployment associated with the existing macroeconomic conditions so that true output increased while reported output increased even more due to covert quality depreciaiton not captured in the official price indices. For the analysis of productivity growth, we are interested in the reporting effects and of the real effects.[31]

It may be useful to look more closely at how these reporting effects could occur. Recall that the ESP established price controls relative to the base-period price of each product produced by each firm. New, higher quality products could be introduced at higher prices reflecting their higher costs. During Phases 1 and 2 (August 1971-January 1973) the controlled prices generally fell relative to the prices which otherwise would have prevailed. This provided an increasing incentive to make covert quality depreciations in existing goods and to claim spurious quality appreciatons in new goods. Or to say the same thing, there was an increasing incentive to publicize every quality improvement and to shade the quality of existing products. If firms reacted to these incentives as we normally suppose, then those collecting data for computing price indices would likely miss more quality depreciation and record more quality appreciation than normal. Controls become progressively less binding under the subsequent Phases III and IV ending de jure on April 30, 1974, with the expiration of legislative authority and de facto in the third quarter with the expiration of certain pricing agreements negotiated in exchange for early decontrol.[32] So during this period firms had an incentive to progressively restore their products to their nominal quality. To the extent price data collectors missed the shading of quality during Phases I and II, they should equally have missed its restoration during the relaxation and removal of controls.

Before going any further, we must consider whether this story is empirically plausible. Some economists, especially those responsible for collecting the price data, have doubted that any significant quality shading could have been missed. However, the price-control hypothesis does not require any huge errors. The estimate in equation (13) of the missed quality decrease — or better, of the decrease in the quality improvement which was missed — only amounts to about 0.2 percent per month (2.5 percent per annum). This magnitude is very small not only in absolute terms but also relative to the supposed margin of error in quality adjustments.[33] Missed quality change always imparts some bias to measured real GNP growth, but price controls impart incentives which change the bias in predictable ways.

Another possible objection is that firms shading quality would be caught by the I.R.S.'s monitoring of the profit margin ceiling. But this is not the case in a balanced inflation in which prices, costs, sales, and profits all rise in proportion. Everyone can accurately report the dollar amounts of revenues, costs, and profits since the profit margin ceiling was purely window dressing absent any effective controls on (quality-adjusted) costs. Thus nominal value added and nominal GNP will be correctly computed; only its division between real GNP and the deflator will be biased.

The text and Darby (1982a) have already shown that misreporting under price controls can explain the anomolous behavior of Okun's Law during the price control period.[34] Okun's Law should underpredict output growth from 1971 III through 1973 I when the growth is overreported and correspondingly overpredict output growth during the decontrol period. For 1971 II to 1974 IV as a whole, Okun's Law predicts total growth in real GNP rather well.[35]

Let us see what other evidence can be offered in support of the reporting hypothesis. A simple check on the hypothesis that the nominal GNP data will be unaffected involves running a simple reduced-form regression explaining nominal GNP (Y) growth by a distributed lag on nominal money (M1B) growth and ΔCD:

$$(15)\quad \Delta \log Y = h_0 + \sum_{i=0}^{7} h_{i+1} \Delta \log M1B_{t-i} + h_9 \Delta CD$$

The estimated regression can be summarized as

$$(16)\quad \Delta\log Y = \underset{(3.53)}{0.0088} + \sum_{i=0}^{7} h_{i+1} \Delta\log M1B_{t-i} - \underset{(-0.03)}{0.0004}\, \Delta CD$$

$$\sum_{i=0}^{7} h_{i+1} = 0.8872$$

$$S.E.E. = 0.0073, \quad \bar{R}^2 = 0.34, \quad D\text{-}W = 1.99, \quad \text{PERIOD} = 1961\ \text{I}\text{–}1980\ \text{III}$$

Thus controls do not appear to have any significant impact on nominal GNP.[36] An analogous regression confirms the hypothesized negative impact of controls on the inflation rate as measured by the GNP deflator PD:[37]

$$(17)\quad \Delta\log PD = \underset{(-0.40)}{-0.0010} + \sum_{i=0}^{7} k_{i+1} \Delta\log M1B_{t-i} - \underset{(-3.19)}{0.0337}\, \Delta CD$$

$$\sum_{i=0}^{7} k_{i+1} = 1.0685$$

$$S.E.E. = 0.0036, \quad \bar{R}^2 = 0.35, \quad D\text{-}W = 2.22, \quad \text{PERIOD} = 1961\ \text{I}\text{–}1980\ \text{III}$$

Thus regression analysis of U.S. data on real GNP, nominal GNP, and the GNP deflator indicates that price controls had no effect on reported total nominal spending, but only upon its division into prices and output. The fact that real output and productivity growth appear to rise and fall relative to that predicted by labor-market conditions strongly supports the reporting hypothesis.

Separate evidence in support of the reporting hypothesis is to be found in comparisons of reported deflated GNP not with inputs but with alternative measures of output. Terborgh (1979) has noted the anomolous behavior of reported real GNP relative to the Federal Reserve index of manufacturing production in the period 1971-1974. As noted by Terborgh, the FRB index is based primarily on counts of physical units. Terborgh shows that although normally the FRB index grows faster than real GNP, this is not true in 1971 and 1972. Furthermore measured real GNP falls sharply relative to the FRB index in 1973, 1974, and 1975.[38] A formal check on whether or not price controls move measured real GNP compared to what would be expected from the Index of Manufacturing Production (IMP) involves running the regression:

$$(18)\quad \Delta\log y = \underset{(9.21)}{0.0052} + \underset{(16.72)}{0.3239}\,\Delta\log IMP + \underset{(3.05)}{0.0355}\,\Delta CD$$

$$S.E.E. = 0.0061, \quad \bar{R}^2 = 0.71, \quad D\text{-}W = 2.02, \quad \text{PERIOD} = 1948\ \text{II}\text{-}1980\text{III}$$

Note that the coefficient on ΔCD is some 0.009 smaller than that estimated in the text for the productivity growth equation. Although the difference is not significant, it is to be expected since IMP includes some deflated as well as physical unit series.[39] It is proposed in future research to follow up these very promising results by using the underlying individual data series on physical units of homogeneous commodities to construct an independent estimate of real GNP for analysis of recent productivity growth.

In summary, there is a considerable body of evidence that the uneven productivity growth reported in 1965-1978 can be explained by reporting biases in 1971-1974 and normal cyclical factors. Darby (1982a) showed that similar adjustments may be required in those countries which adopted programs modeled on the ESP during 1971-1974. These results support the basic conclusion of this paper: that there have been no substantial variations in secular U.S. labor productivity growth after adjustment for changing demographic trends.

APPENDIX B

DATA APPENDIX

The primary data base for this paper is reported in Darby (1982c). Table 8 extracts the data on private employment (PE), total hours worked in the private sector (THWP), the implicit average hours worked in the private sector (AHWP), and gross private product (GPP) from that source. Table 9 reports the data for the five main calculated series: quality-adjusted private employment (QAPE), quality-adjusted total private hours worked (QATHWP), the average years since migration of foreign-born workers by sex (Z_M and Z_F), and the median years of education E.

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FOOTNOTES

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[1]Productivity trend growth rates are normally computed from high-employment to high-employment year to avoid the large cyclical variations in productivity analyzed by such authors as Oi (1962), Fair (1969), Solow (1973), Sims (1974), and Gordon (1979). The figures in the text are for the private-nonfarm-output-per-hour-paid-for definition of labor productivity and are taken from U.S. Council of Economic Advisers (1979, pp. 67-68).

[2]Darby (1982b, 1982c).

[3]As discussed below, the results are not very sensitive to the particular measures chosen. The ratio of GPP to total private hours worked indicates the largest 1965-1978 private hourly productivity slowdown (0.67 percentage points) and is accordingly used. At the other extreme, total private hours paid would indicate only a 0.39 percentage point deceleration.

[4]Immigration was sharply limited by the "national origin" quota system in effect from 1929 until abolished by the Act of October 3, 1965. The average ratio of immigrants (16 and over) to civilian labor force was 1.42, 0.20, and 0.34 percent for 1900-1929, 1930-1965, and 1966-1978, respectively.

[5]The break years 1948 and 1973 are the standard ones in the literature. The year 1916 was chosen as a convenient high employment year.

[6]The estimates are computed from relative earnings for 1929-1970 and 1970-1976, respectively, for finer age groups. The finer age groups were weighted for percentage of total hours worked. Note that the relative wages reflect not only pure age and sex differences in human capital but also the <u>relative</u> amounts of education, all taken as approximately constant. Changes in the average <u>level</u> of education are accounted for in equation (5) below.

[7]See Chiswick (1978, 1979) and Blau (1980). Previously Friedman (1974) had noted that the rapid immigration of the early twentieth century reduced measured growth in real per capita income or, as here, labor productivity.

[8]These parameters were derived as follows. Blau (1980, p. 32) indicates gross log differentials in wages at entry for Ethnic Group 2 (the relevant one for post 1900) of -0.351 for men and -0.183 for women. Now $e^{-0.351} = 0.704$ and $e^{-0.183} = 0.833$. These gross differentials were in part due to education, which is adjusted for separately below. Allowance is made for 1 year of education (see Chiswick, 1978, p. 907) or 7 percent which approximately squares with Blau's results for percent literate. (No allowance was made for differences in mean ages as preliminary calculations suggested any effect was negligible.) Thus the gross wage differential on entry used was (1.07) (0.704) = 0.753 for males and (1.07) (0.833) = 0.891 for females. The estimated effect on the log of real wages of years since migration was 0.0107 for males and 0.0117 for females, and $e^{0.0107} = 1.01076$ and $e^{0.0117} =$

0.01177. Using 1970 data for men, Chiswick (1978) obtained values implying an adjustment factor of about $(1.015)^{Z_M}(0.721)$ for males. A sensitivity check showed that substituting this factor made no significant difference to the results.

[9]Unfortunately, no data was found to make differential adjustments by age group so the same factor was used for both young and old.

[10]The 1909 data came from U.S. Immigration Commission (1911, Table 56, pp. 1521 and 1528). The cells were assigned their mean values (0.5, 1.5, 2.5, 3.5, 4.5, 7.5, 12.5, and 17.5) except for the open cell (20 years and over) for which Blau's value of 30 years was used. The 1970 data were from U.S. Bureau of the Census (1973, Table 18, p. 466) using cell values of 2.65, 7.8, 12.8, 17.8, 22.8, 30.3, 40.3, and 53.1 years for the open (before 1925) cell. The last value was estimated by taking weighted averages of young immigrants arriving 1904 through 1924 who would be 65 or under in 1970.

[11]This value was taken from Chiswick (1978, p. 908) and appears reasonable in terms of such recent cross-section results as reported by Smith and Welch (1977). Yet lower rates of return to education would lower productivity growth in the early period relative to the two later periods, but would not have much effect on the main conclusion of this section: the absence of a secular decline in productivity growth.

[12]Mean years of education were not available, but if the difference is constant the substitution of the median will not affect the growth rates estimated below. Folger and Nam (1964) retroject the 1940 census data back to obtain median estimates for 1930, 1920, 1910. These values of 8.6, 8.4, 8.2, and 8.1 were extrapolated to 8.0 in 1900. Sources for more recent years are given in the data appendix. Log-linear interpolation was used to fill in missing values.

[13]The growth-rate effect of education is separable from those of age, sex, and immigration, but the latter effects are not separable from each other. Because the age-sex adjustment is more important for the last two periods, the effect of the age-sex correction is reported if no adjustment is made for immigrants and then the additional (marginal) adjustment when APE is computed according to equations (1), (2), and (3).

[14]This deceleration is not reflected in the household survey data on average hours worked per person employed in the civilian economy (AHW) but is even a bit larger in the establishment data on hours paid per production or other nonsupervisory employee (AHPN). It might reflect increased moonlighting (higher hours per person employed but less hours per employee in each establishment). The growth in average private hours paid per person employed in the private sector (AHP) is computed as the growth rate of the ratio of total private hours paid for (all employees, private business sector, establishment data) to private employment. The deceleration in this AHP measure is less than in the AHPN measure either due to increased moonlighting or less negative growth in average supervisory hours. The remaining 0.2% discrepancy between the growth rates of the AHW and AHP measures could be attributed to shifts in the government/private employment mix and to less negative growth in average hours worked per government employee, but data is lacking to demonstrate this. Another possibility is a yet unidentified change in reporting procedures for the establishment data — such a change occurred in 1934 with the introduction of the N.I.R.A. codes and minimum wages, but the hours data were adjusted for that.

[15]The growth rate of the average quality of the hours will reflect both the increasing human capital embodied in the labor force and any labor-augmenting technical progress.

[16]Textbook expositions of these results may be found in Solow (1970, pp. 17-38) and Darby (1979, pp. 105-115, 139-140,. 440-441).

[17]If one makes no allowance for measurement error, one could say that productivity growth was a bit low in 1929-1965 relative to 1900-1929 and 1965-1978, but surely this is going too far.

[18]As is well known, technical progress or total factor productivity growth is a euphemism for the increase in output which we cannot explain by the increase in measured inputs. Presumably, the constancy of its average growth rate over substantial periods reflects the law of large numbers and numerous independent contributing factors.

[19]Christensen and Jorgensen (1978, pp. 35, 53) report series on corporate capital input and private domestic captial input with 1929-1948 growth rates of 0.7% and 0.4% per annum, respectively. The NBER-Kendrick capital input series in U.S. Bureau of Economic Analysis (1973, pp. 192-193, Series A65) has an average growth rate of 0.6% per annum during this period. For 1948-1965, Christensen and Jorgensen estimate that private domestic and corporate capital input grew at average rates of 4.0% and 3.8% per annum respectively. The NBER-Kendrick data indicate only a 3.4% growth rate. The preference for the higher growth rate in the latter period is explained in the text below.

[20]The implied average growth rate of capital is 2.21% per annum while output grew at 2.98%; $\exp[(0.0221-0.0298)(36)] = e^{-0.2772} = 0.758$.

[21]Overdeflation of gross investment due to undercorrection for quality changes would have a similar effect.

[22]That is, $[(19)(0.6\%) + (17)(5.6\%)]/36 = 2.96\% \simeq \Gamma y = 2.98\%$.

[23]Obviously, I subscribe to the view that consistent data-collection procedures do not yield consistent data series when incentives or constraints change so as to alter the behavior of the optimizing agents who provide the

data. This differs from the uncertainty principle in that economic analysis can be applied to estimate the nature of the changes.

[24]U.S. Council of Economic Advisers (1979, p. 70).

[25]See Perry (1977, p. 37). In terms of my own short-run productivity growth function — equation (12) below -- the residuals for these seven quarters are 0.0123, -0.0064, 0.0040, 0.0084, 0.0011, 0.0049, and 0.0106, respectively, for a sum of 0.0349. The residuals for the next seven quarters are -0.0068, -0.0058, -0.0037, -0.0079, -0.0117, -0.0076, and 0.0028, respectively, for a sum of -0.0407. The difference (-0.006) is statistically insignificant but could reflect a very small oil-price effect on productivity.

[26]This was the most convenient measure of private productivity available quarterly. All data for this quarterly analysis were taken from the Citibase data bank.

[27]This variable is supposed to capture the differential effects of the demographic adjustments summarized in Tables 2 and 3 above.

[28]The t-statistics are in parentheses below the estimated coefficients.

[29]Thus line 6 refers to equation (12) as reported above.

[30]This estimate is an estimate of the overstatement in deflated private output and thus applies equally well to the annual quality-adjusted private productivity measures reported in Table 4 above.

[31]Thus equation (14) in the main text is a way of estimating the spurious increase in reported output conditional upon whatever real effect on unemployment and employment may have occurred. The reporting hypothesis implies that the official division of nominal amounts into quantities and prices is generally suspect during 1971-1974. Deriving implications from (possibly) incorrectly deflated data is a task not unlike that of George Smiley in LeCarre's Tinker, Tailor, Soldier, Spy. Frequently the data seem to

tell one consistent story if they are taken at face value and another consistent story if they are assumed biased by the price-control program. The challenge is to find cases in which only one of the hypotheses fit.

[32]Charles Cox (1980) uses October 1973 (i.e., 1973 IV instead of 1973 II) as the beginning of the decontrol period since that was the beginning of sector-by-sector decontrol. I believe that the Phase III removal of requirements for prior approval of price increases was a major relaxation since — as explained below — the remaining profit margin ceiling was consistent with any rate of inflation. Some macroeconomic evidence supporting 1973 II instead of 1973 IV as the start of decontrol is offered below, but the issue is not crucial. The same evidence is consistent with Cox's view that the controls had no effect on price levels past 1974 II (as compared to my 1974 III) nor on growth rates past 1974 III.

[33]Economists have traditionally argued that missed quality improvements might imply a 2 percent measured inflation even if the "true" price level was constant. See, for example, Ackley (1961, p. 87), Price Statistics Review Committee (1961, pp. 35-39), and Griliches (1961).

[34]In a simple dynamic Okun's Law regression, one obtains:

$$\Delta \log y = \underset{(14.18)}{0.0089} - \underset{(-13.23)}{0.0180}\Delta u + \underset{(3.24)}{0.0436}\Delta CD$$

S.E.E. = 0.0071, $\bar{R}^2$ = 0.61, D-W = 1.99, PERIOD = 1948 II-1980III

The coefficient on ΔCD is nearly identical to the estimate of 0.04397 obtained in the productivity-growth equation (14) in the text. Note, that although Okun's Law is sometimes reversed to explain Δu given $\Delta \log y$, that form is not appropriate to the current case in which relatively large measurement error is hypothesized for Δlog y as compared to Δu.

[35]See Darby (1976a).

[36]These results are inconsistent with the Barro-Grossman-Evans view discussed above.

[37]This equation was estimated with a first order correction for autocorrelation ($\hat{\rho}$ = 0.5419). Without this correction the coefficient of ΔCD was estimated as -0.0437 (standard error 0.0082, t-statistic -5.3084) and the S.E.E. was 0.0041 with a D-W of 1.13.

[38]Terborgh's use of annual data spreads the adjustment period into 1975 since the <u>average</u> 1974 real GNP data will be overstated on the price control hypothesis.

[39]A formal F-test was conducted for both this regression and the one reported in footnote 34 above to test the implicit hypothesis that the coefficient was the same during the decontrol and control periods. The hypothesis was not rejected.

TABLE 1

Average Annual Growth Rates of Private Employment,
Private Hours, Gross Private Product, and Productivity
1900-1978

Period	Private Employment PE	Average Hours Worked AHWP	Private Hours Worked THWP	Gross Private Product GPP	Hourly Productivity GPP/THWP	Employee Productivity GPP/PE
1900-1978	1.39	-0.24	1.15	3.23	2.08	1.84
Major Periods:						
1900-1929	1.77	-0.22	1.54	3.42	1.88	1.65
1929-1965	0.87	-0.28	0.60	2.98	2.38	2.10
1965-1978	1.96	-0.18	1.78	3.49	1.71	1.53
Subperiods:						
1900-1916	2.09	0.05	2.14	3.64	1.50	1.56
1916-1929	1.38	-0.56	0.81	3.15	2.34	1.78
1929-1948	0.88	-0.17	0.71	2.28	1.57	1.40
1948-1965	0.86	-0.40	0.46	3.75	3.29	2.89
1965-1973	1.84	-0.21	1.63	3.90	2.27	2.06
1973-1978	2.15	-0.13	2.02	2.82	0.80	0.67

Units: Continuously compounded rates in percent per annum computed from the first to the last year of the period.

Source: See Data Appendix, Table 8.

TABLE 2

Growth Rate Effects of Demographic Adjustments to Private Employment
1900-1978

Period	Unadjusted Private Employment	Adjustment for Age and Sex	Additional Adjustment for Immigration	Adjustment for Education	Quality Adjusted Pvt. Emplmt.
1900-1978	1.39	-0.09	0.19	0.38	1.87
Major Periods:					
1900-1929	1.77	0.06	0.06	0.09	1.98
1929-1965	0.87	-0.10	0.29	0.64	1.71
1965-1978	1.96	-0.41	0.21	0.31	2.07
Subperiods:					
1900-1916	2.09	0.08	-0.08	0.07	2.16
1916-1929	1.38	0.04	0.22	0.12	1.75
1929-1948	0.88	-0.04	0.28	0.28	1.40
1948-1965	0.86	-0.17	0.30	1.05	2.05
1965-1973	1.84	-0.47	0.29	0.42	2.09
1973-1978	2.15	-0.31	0.07	0.14	2.04

Units: Continuously compounded rates in percent per annum from the first to the last year of the period.

Note: Adjustments may not add due to rounding.

TABLE 3

Differential Effects of Demographic Adjustments
to Private Employment over Major Periods
1900–1978

Period	Age-Sex Adjustment	Immigration Adjustment	Education Adjustment	Total Adjustment
1900–1929	0.15	-0.13	-0.29	-0.27
1929–1965	-0.01	0.10	0.26	0.35
1965–1978	-0.32	0.02	-0.07	-0.37

Units: Continuously compounded rates in percent per annum computed from the first to the last year of the period.

TABLE 4

Average Annual Growth Rates of Productivity
Measures Adjusted for Age, Sex, Immigration, and Education
1900–1978

Period	Qual. Adj. Private Employment QAPE	Average Hours Worked AHWP	Qual. Adj. Private Hours Worked QATHWP	Gross Private Product GPP	Qual. Adj. Hourly Productivity GPP/QATHWP	Qual. Adj. Employee Productivity GPP/QAPE
1900–1978	1.87	-0.24	1.63	3.23	1.60	1.36
Major Periods:						
1900–1929	1.98	-0.22	1.75	3.42	1.67	1.44
1929–1965	1.71	-0.28	1.43	2.98	1.55	1.27
1965–1978	2.07	-0.18	1.89	3.49	1.60	1.42
Subperiods:						
1900–1916	2.16	0.05	2.21	3.64	1.43	1.48
1916–1929	1.75	-0.56	1.19	3.15	1.96	1.40
1929–1948	1.40	-0.17	1.23	2.28	1.05	0.88
1948–1965	2.05	-0.40	1.64	3.75	2.11	1.71
1965–1973	2.09	-0.21	1.88	3.90	2.03	1.82
1973–1978	2.04	-0.13	1.91	2.82	0.91	0.78

TABLE 5

Implications of Variations in Capital and
Quality-Adjusted Labor Growth for Productivity Growth
1929-1965

Part A — Hourly Productivity Concept

Period	γ	$\Gamma\ell$	Γk	Predicted $\Gamma(y/\ell)$ $\beta=0.20$	$\beta=0.25$	$\beta=0.30$	Actual $\Gamma(y/\ell)$
1929-1948	1.60	1.23	0.6	1.15	1.04	0.93	1.05
1948-1965	1.60	1.64	4.0	1.75	1.79	1.83	2.11
			Alternative Γk Estimates				
1948-1965	1.60	1.64	5.0	1.95	2.04	2.13	2.11
1948-1965	1.60	1.64	5.3	2.01	2.11	2.22	2.11
1948-1965	1.60	1.64	5.6	2.07	2.19	2.31	2.11

Part B — Employee Productivity Concept

Period	γ	$\Gamma\ell$	Γk	Predicted $\Gamma(y/\ell)$ $\beta=0.20$	$\beta=0.25$	$\beta=0.30$	Actual $\Gamma(y/\ell)$
1929-1948	1.36	1.40	0.6	0.93	0.82	0.71	0.88
1948-1965	1.36	2.05	4.0	1.48	1.51	1.54	1.71
			Alternative Γk Estimates				
1948-1965	1.36	2.05	5.0	1.68	1.76	1.84	1.71
1948-1965	1.36	2.05	5.3	1.74	1.83	1.93	1.71
1948-1965	1.36	2.05	5.6	1.80	1.91	2.02	1.71

Units: Continuously compounded rates in percent per annum computed from the first to the last year of the period.

Note: Predicted $\Gamma(y/\ell)$ values are calculated using equation (10).

Table 6

Test Statistics for Alternative Versions of Equation (13)

Line Number	Restrictions	S.E.E.	Value and t-stat for a_7	Value and t-stat for a_8	F-stat for $a_8=a_9=a_{11}=a_{11}=0$	F-stat for $a_9=a_{10}=a_{11}$
1	none	0.00689	0.03679 (2.31)**	-0.00465 (-0.67)	F(4,117) = 0.32	F(3,117) = 0.34
2	$a_9=a_{10}=a_{11}$	0.00684	0.04204 (3.11)***	-0.00329 (-0.50)	--	--
3	$a_8=a_9=a_{11}=a_{11}$	0.00682	0.04397 (3.41)***	--	--	--
4	$a_7=0$	0.00702	--	-0.00878 (-1.28)	F(4,118) = 1.76	F(3,118) = 1.68
5	$a_7=a_9=a_{10}=a_{11}=0$	0.00708	--	-0.00914 (-1.40)*		
6	$a_7=a_8=a_9=a_{10}=a_{11}$	0.00711	--	--	--	--

* Significant at 10 percent level.

** Significant at 5 percent level.

*** Significant at 1 percent level.

TABLE 7

Calculation of Quality-Adjusted Labor Productivity Growth Rates
Adjusted for Price-Control Reporting Biases
1965-1978

	Productivity Measures	
	Hourly Productivity GPP/QATHWP	Employee Productivity GPP/QAPE
Reported Growth, 1965-1973	2.03	1.82
Less, 0.0343/8	- 0.43	- 0.43
Adjusted Growth, 1965-1973	1.60	1.39
Reported Growth, 1973-1978	0.91	0.78
Plus, 0.0343/5	+ 0.69	+ 0.69
Adjusted Growth, 1973-1978	1.60	1.47

Units: Continuously compounded rates in percent per annum computed from the first to the last year of the period.

TABLE 8
Private Employment, Hours, and Output
1900-1978

Year	Private Employment PE	Total Hours THWP	Average Hours AHWP	Gross Product GPP
1900	26692.1	57.2	118.4	103.7
1901	27679.7	59.7	119.1	115.8
1902	28503.1	62.4	120.8	116.9
1903	29173.3	64.1	121.3	122.7
1904	29389.2	63.2	118.7	121.0
1905	30535.2	66.3	119.9	130.0
1906	32257.1	69.0	118.0	145.4
1907	32813.6	70.5	118.6	147.6
1908	31618.7	67.4	117.7	134.7
1909	33376.9	71.2	117.7	151.6
1910	33993.3	73.0	118.5	153.0
1911	34364.6	74.4	119.5	158.0
1912	35570.0	76.7	119.0	165.5
1913	36386.6	77.3	117.3	172.1
1914	35589.3	75.8	117.6	158.0
1915	35477.5	75.2	117.0	162.3
1916	37268.7	80.6	119.4	185.7
1917	37350.6	82.3	121.7	178.4
1918	37265.9	81.6	120.9	185.8
1919	37906.7	79.0	115.1	193.4
1920	38044.5	80.0	116.1	195.2
1921	35805.3	72.1	111.1	190.7
1922	38402.7	77.5	111.4	201.9
1923	41176.6	83.6	112.1	229.8
1924	40703.8	81.7	110.8	236.6
1925	42297.3	84.6	110.4	242.1
1926	43355.5	87.6	111.5	258.3
1927	43292.4	87.1	111.1	260.5
1928	43419.6	87.8	111.7	263.4
1929	44565.0	89.6	110.9	279.7
1930	42332.0	83.4	108.8	249.2
1931	39136.0	76.5	107.9	228.3
1932	35715.0	67.8	104.7	191.9
1933	35594.0	67.0	104.0	186.8
1934	37591.0	72.0	105.7	202.6
1935	38779.0	75.9	108.0	223.3
1936	40742.0	81.6	110.6	253.6
1937	42544.0	86.7	112.5	270.0
1938	40337.0	79.2	108.4	252.9
1939	41755.0	83.3	110.1	276.5
1940	43318.0	87.3	111.2	301.2
1941	45690.0	94.7	114.4	346.7
1942	48267.0	102.1	116.8	377.0

TABLE 8 (cont.)
Private Employment, Hours, and Output
1900-1978

Year	Private Employment PE	Total Hours THWP	Average Hours AHWP	Gross Product GPP
1943	48390.0	105.8	120.7	399.7
1944	47917.0	104.4	120.3	420.4
1945	46876.0	98.7	116.2	413.9
1946	49655.0	99.7	110.8	403.1
1947	51564.0	101.8	109.0	412.3
1948	52693.0	102.6	107.5	431.5
1949	51795.0	98.8	105.3	429.8
1950	52892.0	100.5	104.9	470.0
1951	53572.0	104.0	107.2	500.4
1952	53641.0	104.7	107.7	515.3
1953	54534.0	104.9	106.2	538.5
1954	53358.0	100.6	104.1	531.8
1955	55256.0	104.1	104.0	572.9
1956	56521.0	105.6	103.1	584.8
1957	56455.0	104.2	101.9	594.7
1958	55197.0	100.0	100.0	590.6
1959	56547.0	103.3	100.8	629.5
1960	57425.0	104.5	100.4	641.9
1961	57152.0	102.8	99.3	657.8
1962	57812.0	104.8	100.1	697.8
1963	58537.0	105.6	99.6	727.3
1964	59709.0	107.7	99.6	767.5
1965	61014.0	111.1	100.5	816.6
1966	62111.0	113.9	101.2	864.0
1967	62981.0	115.7	101.4	883.7
1968	64081.0	117.4	101.1	925.6
1969	65707.0	120.2	101.0	952.0
1970	66073.0	117.7	98.3	949.5
1971	66239.0	118.2	98.5	985.7
1972	68368.0	121.8	98.3	1048.1
1973	70677.0	126.6	98.9	1115.9
1974	71765.0	127.4	98.0	1105.6
1975	70097.0	122.6	96.6	1089.0
1976	72614.0	126.2	96.0	1154.1
1977	75419.0	132.1	96.7	1223.3
1978	78701.0	140.0	98.2	1285.0

Sources: PE, THWP, and GPP are from Darby (1982c), Tables A7, A19, and A20, respectively.
AHWP = (THWP/PE) * (PE1958) so that the base year value (1958 = 100) of the THWP index is preserved.

TABLE 9
Quality-Adjusted Private Employment and Hours, Years since Migration, and Median Education
1900-1978

Year	Quality-Adjusted Private Employment QAPE	Quality-Adjusted Private Hours QATHWP	Years since Migration Males ZM	Years since Migration Females ZF	Median Education E
1900	37942.2	43.8	22.7	7.4	8.0
1901	39350.9	45.7	21.9	7.7	8.0
1902	40532.7	47.7	20.7	8.0	8.0
1903	41431.6	49.0	19.2	8.2	8.0
1904	41765.6	48.3	18.1	8.4	8.0
1905	43331.6	50.6	16.6	8.5	8.0
1906	45671.1	52.5	15.4	8.6	8.1
1907	46404.9	53.7	14.0	8.6	8.1
1908	44934.6	51.5	13.6	8.8	8.1
1909	47463.3	54.4	13.3	9.0	8.1
1910	48393.8	55.9	12.6	9.2	8.1
1911	48977.3	57.0	12.3	9.3	8.1
1912	50992.5	59.1	12.1	9.4	8.1
1913	51841.0	59.3	11.5	9.4	8.1
1914	50808.7	58.2	11.1	9.4	8.1
1915	50909.3	58.1	11.4	9.8	8.1
1916	53605.6	62.4	11.8	10.3	8.2
1917	54105.5	64.2	12.2	10.7	8.2
1918	55203.1	65.0	12.7	11.2	8.2
1919	56037.4	62.9	13.1	11.7	8.2
1920	56052.4	63.5	13.3	11.9	8.2
1921	53037.2	57.4	13.1	11.9	8.2
1922	56846.4	61.7	13.5	12.2	8.2
1923	60902.8	66.5	13.6	12.4	8.3
1924	60480.9	65.3	13.5	12.5	8.3
1925	63006.9	67.8	13.8	12.8	8.3
1926	64819.4	70.4	14.1	13.2	8.3
1927	65015.6	70.4	14.3	13.5	8.3
1928	65573.6	71.4	14.6	13.8	8.4
1929	67314.5	72.8	15.0	14.1	8.4
1930	64485.5	68.4	15.3	14.4	8.4
1931	60599.4	63.7	15.9	14.9	8.4
1932	56185.0	57.4	16.4	15.5	8.4
1933	58297.0	59.1	17.0	16.0	8.5
1934	62507.4	64.4	17.6	16.6	8.5
1935	64679.0	68.1	18.2	17.1	8.5
1936	68746.7	74.1	18.7	17.7	8.5
1937	70085.5	76.8	19.3	18.2	8.5
1938	68357.0	72.2	19.8	18.7	8.6
1939	70101.8	75.2	20.3	19.1	8.6
1940	72088.2	78.2	20.7	19.6	8.6

TABLE 9 (cont.)
Quality-Adjusted Private Employment and Hours, Years since Migration, and Median Education
1900-1978

Year	Quality-Adjusted Private Employment QAPE	Quality-Adjusted Private Hours QATHWP	Years since Migration Males ZM	Years since Migration Females ZF	Median Education E
1941	75464.1	84.2	21.3	20.1	8.7
1942	78649.7	89.5	21.8	20.6	8.7
1943	78269.2	92.1	22.4	21.2	8.8
1944	78028.1	91.5	22.9	21.7	8.9
1945	77375.4	87.7	23.5	22.2	8.9
1946	81825.3	88.4	24.0	22.5	9.0
1947	85664.4	91.0	24.3	22.6	9.1
1948	87865.6	92.0	24.6	22.8	9.2
1949	87342.5	89.6	24.9	22.9	9.2
1950	89554.1	91.5	24.9	22.9	9.3
1951	92021.9	96.1	25.0	23.0	9.4
1952	93673.9	98.4	25.0	23.0	9.5
1953	96384.6	99.7	25.3	23.1	9.7
1954	95722.8	97.1	25.4	23.2	9.8
1955	99339.2	100.7	25.4	23.2	9.9
1956	102321.0	103.0	25.2	23.0	10.1
1957	103459.7	102.7	25.0	22.8	10.2
1958	102595.6	100.0	25.0	22.8	10.3
1959	105794.4	104.0	25.0	22.7	10.5
1960	108122.0	105.9	25.0	22.6	10.6
1961	110739.3	107.2	25.0	22.5	11.0
1962	115282.0	112.4	24.9	22.5	11.4
1963	117888.0	114.4	24.7	22.3	11.5
1964	121223.5	117.6	24.6	22.2	11.7
1965	124412.4	121.9	24.5	22.0	11.8
1966	128389.8	126.7	24.3	21.8	12.0
1967	130538.4	129.0	24.1	21.5	12.0
1968	133813.7	131.9	23.6	21.1	12.1
1969	136911.9	134.8	23.3	20.9	12.1
1970	138141.3	132.4	22.9	20.7	12.2
1971	138575.5	133.1	22.6	20.5	12.2
1972	142226.6	136.3	22.3	20.3	12.2
1973	146996.5	141.6	22.0	20.1	12.3
1974	149302.6	142.7	21.6	19.9	12.3
1975	147144.3	138.5	21.4	19.8	12.3
1976	152150.0	142.3	21.1	19.6	12.4
1977	156906.0	147.8	20.7	19.3	12.4
1978	162812.9	155.8	20.1	18.9	12.4

TABLE 9 (cont.)
Quality-Adjusted Private Employment and Hours, Years since Migration, and Median Education
1900-1978

Sources: QAPE was computed using equations (1) through (5) as explained in the text and data from Darby (1982c). QATHWP = (QAPE * AHWP)/QAPE1958 so that the base year (1958) is 100.0. ZM and ZF were computed using equation (4), 1909 and 1970 benchmarks, and data from Darby (1982c). Missing values for E were logarithmically interpolated between the following observations:
1910, 1920, 1930 Folger and Nam (1964, p. 253); 1900, Extrapolated by author from above values; 1940, 1950, 1960, CPR # 356; 1962, 1964, 1965, 1966, CPR # 158; 1967, CPR # 169; 1968, CPR # 182; 1970, CPR # 207; 1971, CPR # 229; 1972, CPR # 243; 1973, 1974, CPR # 274; 1975-1979, CPR # 356;
where CPR is short for U.S. Bureau of the Census, Current Population Reports, Series P-20, and the issue dates of the reports are # 158 December 19, 1966, # 169 February 9, 1968, # 182 April 28, 1969, # 207 November 30, 1970, # 229 December 1971, # 243 November 1972, # 274 December 1974, and # 356 August 1980.

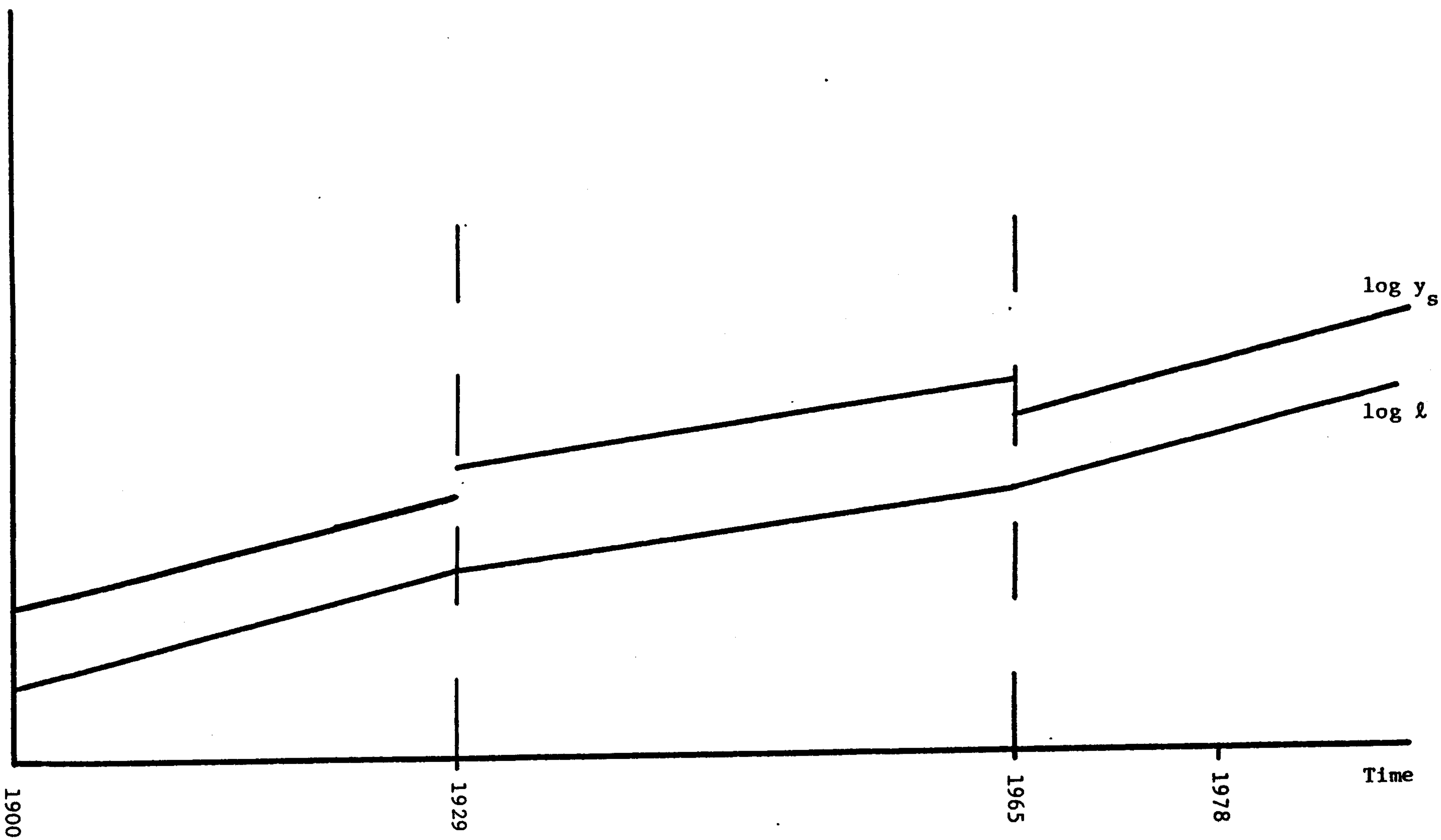

Figure 1

Steady-State Behavior of Labor and Output under Capital-Deepening Hypothesis

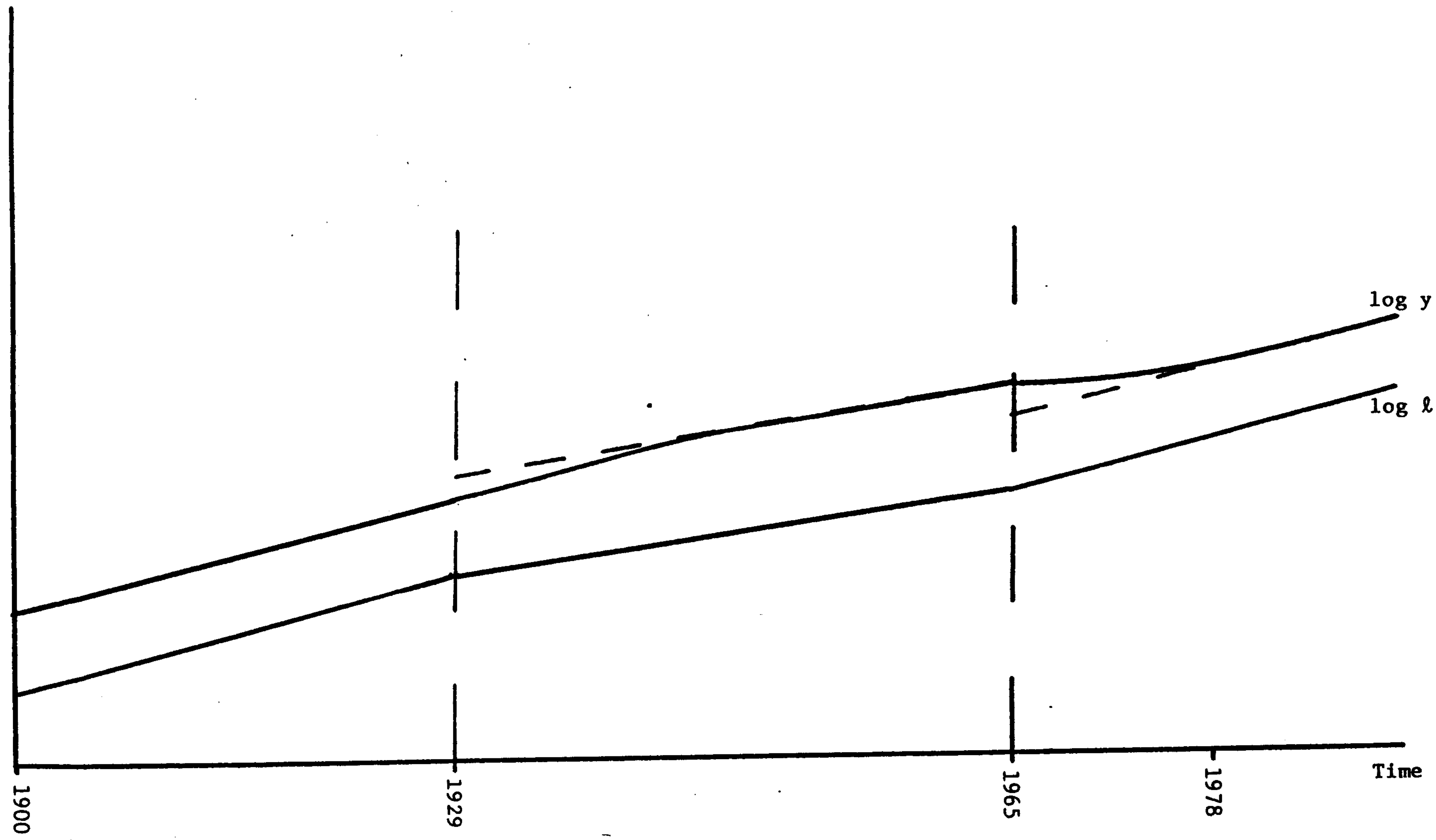

Figure 2

Adjustment of Actual to Steady-State Output under Capital-Deepening Hypothesis

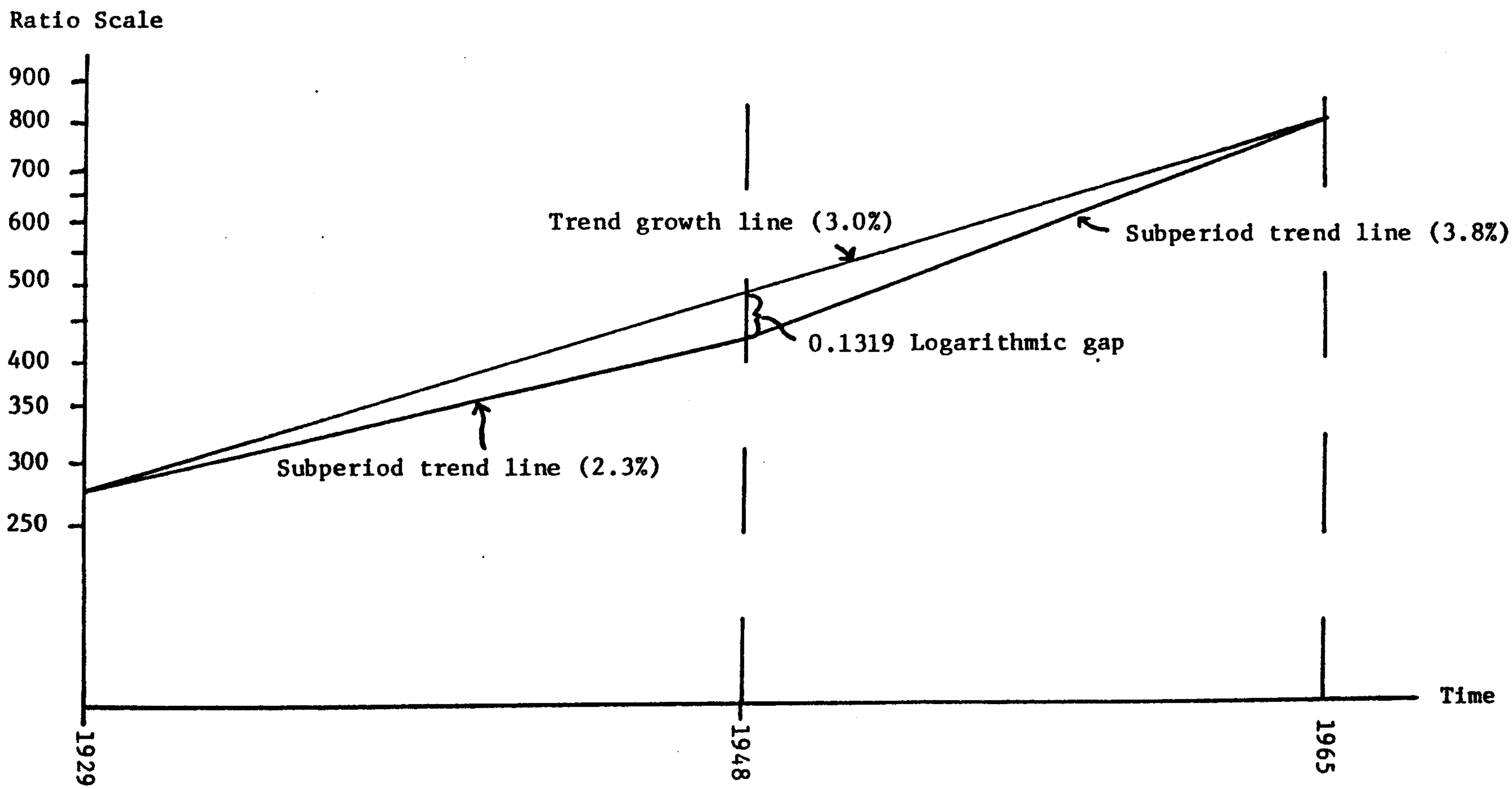

Figure 3

Growth Trends of Gross Private Product, 1929-1965

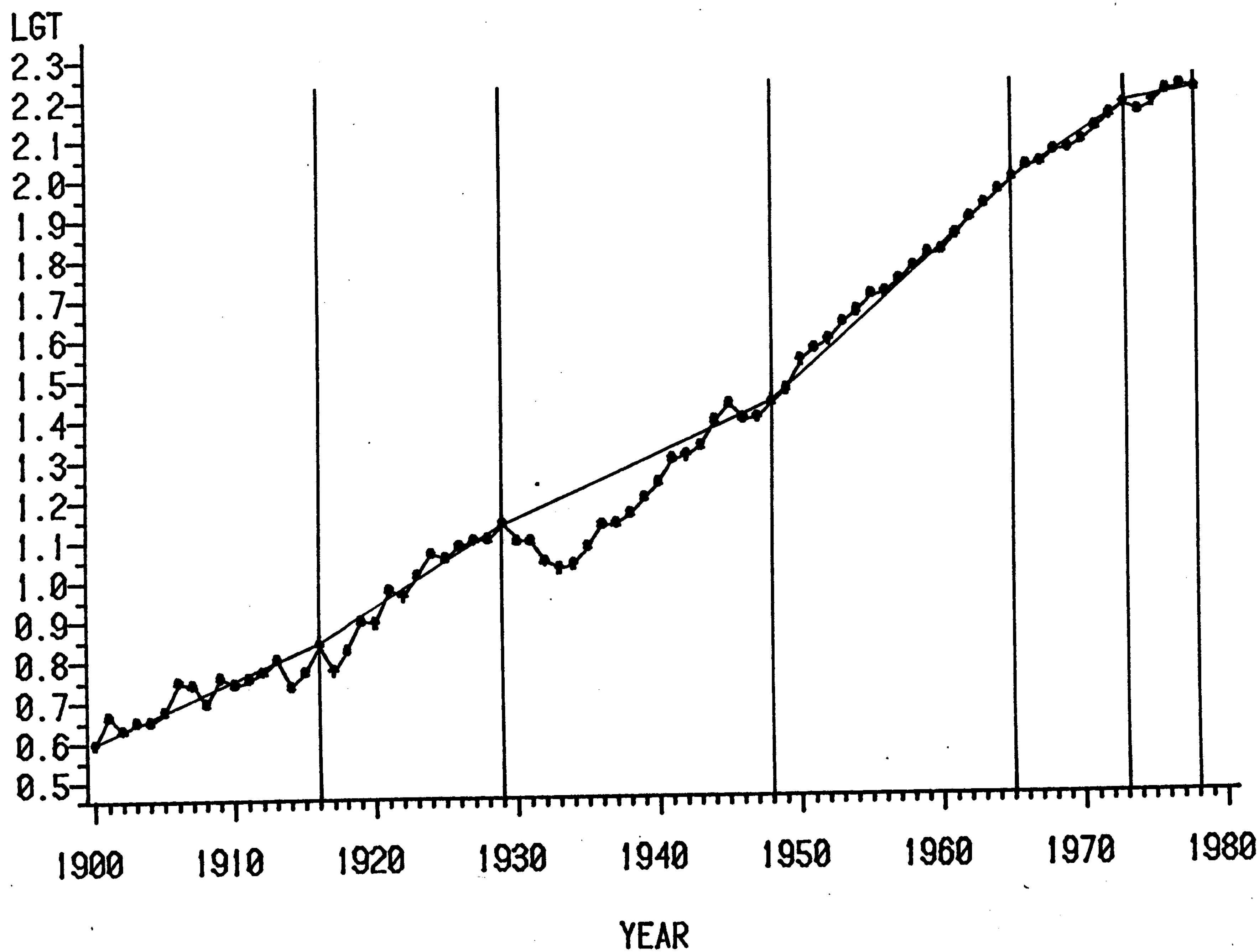

Figure 4
Logarithm of Hourly Productivity
log(GPP/THWP)

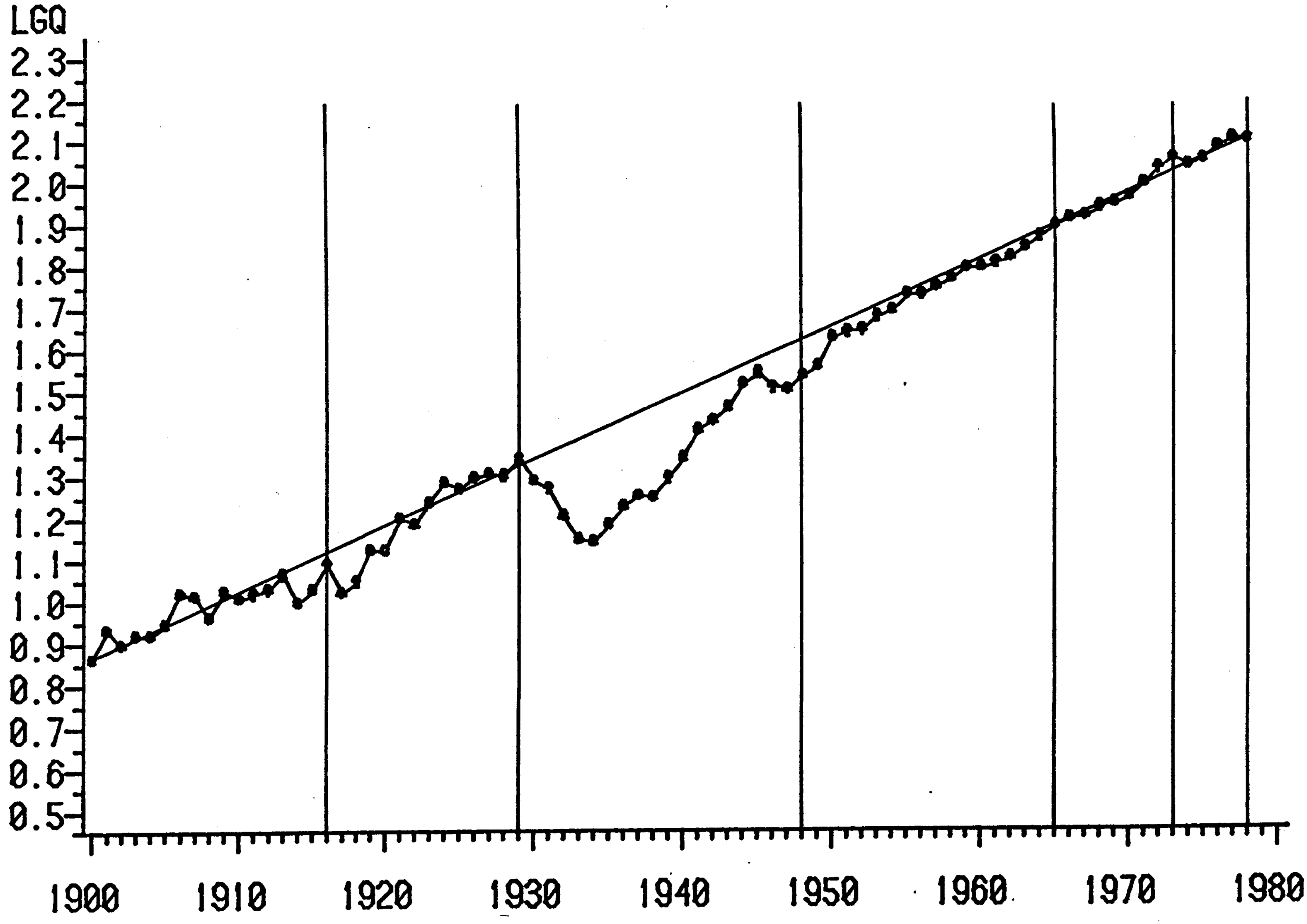

Figure 5
Logarithm of Quality-Adjusted Hourly Productivity, 1900-1978
log (GPP/QATHWP)