Procyclical Labor Productivity and Competing Theories of the Business Cycle: Some Evidence from Interwar U.S. Manufacturing Industries

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We study the phenomenon of short-run increasing returns to labor (SRIRL) in a sample of 10 interwar U.S. manufacturing industries. Our main findings are that SRIRL was common in the interwar period and that the pattern of SRIRL across industries was similar to that observed in the postwar period. We argue that, since presumably the Depression was not caused by technical regress, these findings are inconsistent with the claim of real business cycle theorists that SRIRL is in general due to procyclical technological shocks. We propose tests for discriminating between two other leading explanations of SRIRL but find that our conclusions differ by industry.

I. Introduction

Since its discovery by Hultgren (1960), the procyclical behavior of average labor productivity, also known as short-run increasing returns to labor (SRIRL), has achieved the status of a basic stylized fact of macroeconomics. The ubiquitous nature of procyclical productivity has been confirmed by studies at levels of aggregation ranging from

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the firm to the national economy, and for a variety of countries and sample periods.

Much of the original research on procyclical productivity was undertaken during the 1960s and early 1970s, contributions being made by Brechling (1965), Kuh (1965), Ball and St. Cyr (1966), Solow (1968), Fair (1969), and Sims (1974), among others. More recently, attention has been refocused on SRIRL in the context of research on real business cycles (Prescott 1986*b*) and by the work of Fay and Medoff (1985), Hall (1987, 1988*a,* 1988*b*), Rotemberg and Summers (1988), and Chirinko (1989). The reason for the renewed interest in SRIRL is that, as has become increasingly clear, the choice of explanation of SRIRL effectively entails a choice among some leading contemporary models of the business cycle.

Three major explanations for SRIRL have been advanced: technology shocks, true increasing returns, and labor hoarding. Each explanation is closely associated with a competing model of the cycle.

The *technology shocks* explanation is favored by the competitive real business cycle approach, as exposited by Prescott (1986*b*). In the real business cycle model, changes in technology are the driving force behind cyclical fluctuations, and intertemporal substitution in labor supply is a key propagation mechanism. Labor productivity is procyclical in the real business cycle model, despite the assumption of diminishing marginal returns to labor input, because booms are periods in which technological conditions are particularly favorable. Labor input rises in booms to take advantage of this opportunity to be especially productive and thus to earn a real wage that is temporarily high.

The idea that SRIRL reflects *true increasing returns* in the production function (for a fixed level of technology) has been advocated by Hall (references noted above). Supporting evidence has been presented by Ramey (1987), Chirinko (1989), and others. Thus Hall characterizes business cycles as movements along a fixed production function, while Prescott argues that the production function itself shifts over the cycle. Genuine increasing returns are the essential component of models that characterize the cycle as a period of optimal bunching of production. Increasing returns usually imply a noncompetitive industry market structure, although this is not necessarily the case if the increasing returns are external to the firm (Murphy, Shleifer, and Vishny 1989). We shall focus below on the case in which the increasing returns are internal to the firm but shall comment briefly on the external increasing returns case.

The traditional explanation for SRIRL is *labor hoarding,* arising from the quasi fixity of labor (Becker 1962; Oi 1962; Rosen 1968). This is the explanation usually embraced by Keynesians. The idea is that, if the labor force cannot be costlessly adjusted in the short run, it may pay firms to smooth labor input over the cycle (i.e., "hoard" labor in downturns).[1] With hoarded labor, firms utilize labor more intensively in booms than in recessions; this variable utilization over the cycle creates the illusion of increasing returns.[2] The labor hoarding explanation is attractive to Keynesians because it allows the observation of SRIRL to be reconciled with the Keynesian view that most cycles are demand driven, without abandoning the assumption of diminishing returns in the production function. An additional connection between labor hoarding and the Keynesian approach has recently been provided by Rotemberg and Summers (1988), who show that labor hoarding may in some cases be a consequence of price rigidity.

Because the competing theories' explanations for SRIRL are so clearly differentiated and because choosing among these theories is of such great practical importance, evidence from any source on the reason we observe SRIRL should be welcome. In this paper we study the SRIRL phenomenon in a sample of U.S. manufacturing industries drawn from the interwar period (1923–39). This is a period, obviously, of extreme cyclical variation. More important, there is a potential identifying restriction that we are much more willing to apply to this period than to the postwar era; specifically, we believe that it is quite unlikely that the preponderance of interwar cyclical variation (at least during the 1930s) was due to technological shocks to the production functions of individual manufacturing industries. Under this restriction, if the real business cycle theory is true, SRIRL should have been much less pronounced in the Depression era than in the postwar era. We find, on the contrary, that labor productivity was, if anything, more procyclical before World War II than after. In our view, and as is explained in more detail below, this constitutes a strong rejection of the technological shock theory of SRIRL and, consequently, of the real business cycle approach.

This leaves two potential explanations of SRIRL in the interwar data, true increasing returns and labor hoarding. We propose two

[1] An alternative to costly adjustment as a motivation for labor hoarding is that there is some fixed quantity of "overhead labor," whose presence is necessary for operation of the production process. If some overhead labor is counted with production workers, what appears to be SRIRL may be observed in the data even though true marginal costs are constant or increasing. We emphasize the costly adjustment motive in this paper, but we return to the issue of overhead labor in the conclusion.

[2] It should be noted that labor hoarding does not necessarily imply procyclical productivity. Additional necessary conditions are that the intensity of labor utilization can be varied and that the firm finds it profitable in the short run to substitute increases (decreases) in the rate of labor utilization for increases (decreases) in measured employment or hours of work.

tests for distinguishing between these explanations. Both tests are based on the idea that, if there are true increasing returns (and if nonlabor inputs are held fixed), current industry output and current industry labor input should be "sufficient statistics" for each other; that is, given current industry output, no other variable should help predict the contemporaneous level of industry labor input, and vice versa. Using these tests, we can reject pure increasing returns in favor of labor hoarding for some of the industries in our sample but not others. We are thus unable to draw any sweeping conclusions about the relative importance of increasing returns and labor hoarding in interwar industry; it may simply be the case that both of these factors help explain the observation of interwar SRIRL.

The rest of the paper is organized as follows: Section II describes a simple common framework for thinking about alternative explanations of short-run increasing returns to labor. Section III briefly describes the interwar data set. That SRIRL holds for the interwar period is documented in Section IV. Section V discusses the implications of this finding for the technological shocks hypothesis, and Section VI takes up increasing returns and labor hoarding. Section VII presents conclusions.

II. Alternative Explanations for SRIRL: A Common Framework

Recent work on SRIRL for the most part has been couched in terms of explaining the behavior of the "Solow residual," or output minus factor-share-weighted inputs. However, only under the competitive real business cycle approach does the Solow residual have a straightforward economic interpretation (as a measure of disembodied technical progress); under the alternative approaches, the Solow residual does not correspond to any fundamental economic concept. We find it clearer, therefore, to avoid the Solow residual altogether and to use the more primitive analytical framework of the production function itself. We show in this section that the alternative explanations of SRIRL can be expressed in simple econometric terms as alternative interpretations of an estimated regression coefficient in a production equation.

Consider the Cobb-Douglas production function

$$Q_t = A_t K_t^{\alpha} N_t^{\beta}, \tag{1}$$

where Q is value-added production,[3] A is an indicator of Hicks-

[3] In our empirical application we have series on only total physical output, not value added. We must therefore assume that, while capital and labor may be substitutable for each other, the capital-labor aggregate is used in fixed proportions with materials.

neutral technical progress, and K and N are measures of capital and labor input. We make no presumption of constant returns to scale. If there is a distinction between the ex ante and ex post production functions, as in the "putty-clay" model, equation (1) is the ex post production function.

Direct estimation of (1) would be complicated by nonlinearity and the likelihood of nonstationarity; we therefore take logs and difference. Equation (1) becomes

$$q_t = \alpha k_t + \beta n_t + \epsilon_t, \quad (2)$$

where lowercase letters denote log differences and $\epsilon = \Delta \ln A$. In the estimation below we add a constant term to (2) so that the mean of ϵ is zero.

Under competition and constant returns, the parameter β would equal labor's share. However, ordinary least squares (OLS) estimates of (2) on time-series data typically yield estimated values of β much larger than labor's share. Indeed, estimates of β frequently equal 1.0 or greater, implying that the rate of growth of average labor productivity, $q - n$, is procyclical (increasing in n). This is the SRIRL puzzle.

The alternative explanations of SRIRL given in the Introduction can be interpreted as explanations of why the OLS estimate of β in equation (2) exceeds the observed income share received by labor.

1. According to the competitive real business cycle theory, the true value of β equals labor's share. However, OLS estimates of β are biased upward because of a positive correlation between the independent variable n and the error term ϵ in (2). This correlation arises because when productivity growth is temporarily high (ϵ is large), it is optimal also to increase labor input (n is high). More formally, the bias of the OLS estimate is $\rho_{n\epsilon}\sigma_\epsilon/\sigma_n$, where $\rho_{n\epsilon}$ is the correlation of n and ϵ, and σ_n and σ_ϵ are their standard deviations. If intertemporal substitution in labor supply causes $\rho_{n\epsilon}$ to be positive, the bias term will be positive.

2. Under an increasing returns approach and with no significant technological shocks, the OLS estimate of β is a correct estimate of the technological parameter β in equation (2).[4] In this view, the estimate of β exceeds one because there are true increasing returns. With a monopolistic or a monopolistically competitive market structure,

[4] Strictly speaking, the variance of the productivity shock ϵ cannot be zero since then the estimated production function (2) would have to fit the data perfectly. Since we do not expect to see a perfect fit, we must allow for $\mathrm{var}(\epsilon) > 0$; ϵ must then be interpreted as measurement error or as unpredictable production variations uncorrelated with employment in order for the OLS estimate of β to be unbiased. Alternatively, if $\mathrm{var}(\epsilon)$ is small relative to the variance of product demand and labor supply shocks, which also affect equilibrium employment, the OLS estimate of β will be only slightly biased.

labor's share in this case is $\beta(1 - \theta) < \beta$, where θ ($0 < \theta < 1$) is the inverse elasticity of the demand for the firm's output.

3. With labor hoarding, (2) is misspecified in that an unobserved factor of production, labor effort or labor utilization, is omitted from the right side of the equation. In this approach, the true production function is not (2) but

$$q_t = \alpha k_t + \beta n_t + \delta e_t + \epsilon_t, \tag{3}$$

where e is the growth rate of labor effort.[5] Omission of the effort term implies that the expected value of the OLS estimate of β will be $\beta + \delta\gamma$, where γ is the coefficient on n from the regression of e on k and n. Presumably $\delta > 0$ (more effort leads to more output) and $\gamma > 0$ (if firms respond to more demand both by requiring more effort in the short run and by using more measured labor input, then growth in effort and measured labor input will be positively correlated). Therefore, the bias term is positive, and the estimated value of β will exceed the true value.

Labor's share when there is labor hoarding will depend in a complicated way on factors such as worker's compensation for effort, the rate of employment adjustment, and market structure; but again labor's share should normally be below the estimated value of β.

The goal of this paper is to try to distinguish among these three interpretations of the SRIRL finding, using data from the interwar period. We briefly discuss these data before turning to the analysis.

III. Data

Most studies of SRIRL have used postwar data (a notable exception is the original Hultgren [1960] paper; see also Bernanke and Powell [1986]). In this paper, we examine relatively disaggregated interwar data.

The data we use are quarterly (aggregated up from monthly),[6] are roughly at the level of the two-digit manufacturing industry, and cover the period 1923:1–1939:4. (Most of the data are not available before 1923; after 1939, war production seriously affected the composition of industrial outputs, rendering questionable the assumption that the same production function applied.) Industry-level data rather than measures for total manufacturing were used to reduce aggregation bias and to allow us to avoid those industries whose production indices are based on scaled-up input measures rather than

[5] An alternative interpretation of e is that it is the weighted change in utilization of both capital and labor.

[6] We temporally aggregated in the hope that it would reduce the effects of possible measurement error or temporal misalignments of data series from different sources. None of our results depends in any crucial way on this aggregation.

TABLE 1

LABOR'S SHARE, INDUSTRY SIZE, AVERAGE EMPLOYMENT, AND CONCENTRATION RATIOS FOR SAMPLE INDUSTRIES IN 1935

Industry	Labor's Share	Number of Establishments	Average Employment*	Concentration Ratio†
Steel	.477	8,105	108	.394
Lumber	.504	16,127	36	.109
Autos	.486	946	410	.739
Petroleum	.307	395	196	.361
Textiles	.542	22,847	74	.136
Leather	.528	3,506	89	.232
Rubber	.433	466	246	.619
Pulp	.378	779	163	.167
Stone, clay, glass	.381	5,846	41	.376
Nonferrous metals	.404	5,411	40	.385

* Yearly average employment of wage earners; excludes salaried personnel and proprietors. These data and the data on labor's share and the number of establishments are taken from the 1937 and/or 1939 *Biennial Census of Manufactures*.

† Four-firm concentration ratio, defined as the proportion of industry value added attributable to the four largest (by value added) firms in the industry. These ratios were calculated from data contained in *The Structure of the American Economy*, U.S. National Resources Committee (1939).

on direct measures of physical output. We carried out all analyses for both a 1924–39 sample period (the first year of data is reserved to allow for differencing and lags) and a 1929–39 sample period (in order to isolate the experience of the Depression).

Data for the whole 1923–39 sample were found for the following eight industries, which are similar to those used by Bernanke (1986): (1) iron and steel and their products; (2) lumber and allied products; (3) automobiles; (4) petroleum refining; (5) textiles and their products; (6) leather and its products; (7) rubber and allied products; and (8) pulp, paper, and allied products. We also used data for two additional industries for the period 1932–39: (9) stone, clay, and glass and their products and (10) nonferrous metals and products.

Collectively, these 10 industries accounted for about one-fifth of interwar manufacturing employment. Additional information about these industries is presented in table 1.

The basic data in this study refer to output and labor input in each industry; other types of data used are described below at the relevant points. Output was measured by components of the Federal Reserve index of industrial production. Labor input in each industry is measured as total hours of work (employment times average weekly hours). The principal source for data on employment and hours is the Bureau of Labor Statistics (BLS),[7] supplemented by the *Monthly*

[7] See in particular BLS bulletin no. 610, "Revised Indexes of Factory Employment and Payrolls, 1919–1933" (February 1935) and updates in BLS mimeos "Revised Index Numbers of Factory Employment and Pay Rolls" (September 1938) and "Index Numbers of Factory Employment and Pay Rolls" (May 1940).

Labor Review and the National Industrial Conference Board data provided in Beney (1936). All data used in this paper are available on request. Further details on the sources of the data and adjustments made appear in Parkinson (1990), also available on request.

IV. SRIRL in the Interwar Period

In this section we document the existence of SRIRL in our sample of interwar U.S. manufacturing industries.

Estimation of equation (2) requires data on output and on capital and labor inputs for each industry. As described in Section III, data on output and labor input are available on a monthly basis; we have aggregated them up to quarterly. Capital stock data, however, are much harder to come by.

We constructed industry capital stock series using data from Creamer, Dobrovolsky, and Borenstein (1960) and Dewhurst et al. (1955). Our procedure was to combine benchmark industry capital stock estimates, available for 1929 and 1937, with annual gross investment figures to obtain annual industry capital stocks; quarterly estimates were then made by interpolation. Unfortunately, however, estimation of the log-differenced production function (2) using these constructed series yielded estimates of the coefficient on the capital stock that were never statistically significant and often had the wrong sign. Presumably this reflected the low quality of the capital stock data, especially at higher frequencies. Alternatively, if there was persistent excess capacity throughout the period, it is possible that the size of industry capital stocks was (on the margin) irrelevant to industry production rates. In any case, in subsequent regressions we excluded the capital stock series, allowing any trend growth in capital to be picked up by the industry-specific constant terms.[8] It is important to note that the estimated coefficients on labor input were essentially the same with or without inclusion of the capital series.[9]

Results from OLS regressions of the growth rate of industry output on the growth rate of industry labor input and a constant (and with capital input excluded) are shown in table 2. (Seasonal dummies were also included here and in subsequent regressions.) Column 1 of the table shows the estimated coefficient on labor input (β) for the whole sample period (1924 : 1–1939 : 4). Column 2 shows the estimated coef-

[8] Gross investment rates were of course very low during the Depression, so the trend in the capital stock was probably negative for most industries.

[9] At the suggestion of the referee, we also repeated our analyses using growth in a combined capital-labor aggregate, with capital and labor weighted by 1935 industry factor shares, in place of growth in labor input. The coefficients on labor input implied by this alternative procedure were in all cases virtually identical to those reported here.

TABLE 2

ESTIMATES OF THE LABOR INPUT COEFFICIENT

Industry	Ordinary Least Squares 1924–39 (1)	Ordinary Least Squares 1929–39 (2)	Instrumental Variables 1924–39 (3)	Instrumental Variables 1929–39 (4)	Postwar Ordinary Least Squares, 1955–88 (5)
Steel	1.53	1.51	1.48	1.45	1.66
	(.17)	(.17)	(.19)	(.18)	(.10)
Lumber	1.11	1.07	1.06	1.01	.86
	(.04)	(.05)	(.04)	(.04)	(.05)
Autos	1.26	1.21	1.33	1.20	1.05
	(.15)	(.15)	(.21)	(.21)	(.06)
Petroleum*	.36	.42	.96	.80	−.04
	(.10)	(.07)	(.40)	(.38)	(.03)
Textiles	1.03	1.09	1.34	1.12	1.03
	(.12)	(.17)	(.28)	(.36)	(.13)
Leather	.61	.58	.69	.71	.83
	(.10)	(.08)	(.08)	(.08)	(.03)
Rubber	1.21	1.21	1.30	1.27	.98
	(.06)	(.07)	(.10)	(.10)	(.06)
Pulp	1.10	1.11	1.04	.99	1.04
	(.10)	(.10)	(.09)	(.09)	(.38)
Stone, clay, glass	...	1.11	...	.99	.94
		(.07)		(.11)	(.10)
Nonferrous metals	...	1.38	...	1.18	1.23
		(.03)		(.10)	(.07)

NOTE —Data are quarterly. Standard errors are in parentheses. All regressions include a constant and three seasonal dummy variables. The sample periods for the interwar regressions are 1924:1–1939:4 for cols. 1 and 3 and 1929:1–1939:4 for cols. 2 and 4 (1933:1–1939:4 for stone, clay, and glass and nonferrous metals). The sample period for the postwar regression, col. 5, is 1955:2–1988:4 (1958:2–1988:4 for pulp) The instruments for the instrumental variables regressions are the current value and one lagged value of the log differences of real government expenditure, the currency/deposit ratio, and real deposits of failed banks.

* Using monthly data for the postwar regression results in a coefficient of .07 with a standard error of .04. Using quarterly data and adding dummy variables for each oil shock, for the 1969 and 1980 oil industry strikes and the post-1964 change in the trend of industry employment, and allowing for changes in the seasonal pattern after each shock change this coefficient to −.06 with a standard error of .04.

ficient when the sample period is restricted to the Depression period (1929:1–1939:4). For comparison, column 5 shows the estimated labor input coefficient for the same industries (or for as close a match as the data permitted) over the postwar period. (Ignore cols. 3 and 4 for now.) As in the case of the interwar industries, output for the postwar industries is measured by the Federal Reserve industrial production index, and labor inputs come from the BLS; sample periods are given in the notes to the table. The reported standard errors were calculated using the method suggested by Wooldridge (1989) and are robust to heteroskedasticity and serial correlation.[10] Conventional OLS standard errors (not reported) were generally similar to the

[10] Wooldridge's method is similar in spirit to those suggested earlier by White (1984) and others; its principal advantage is computational simplicity.

robust standard errors; in the few cases in which they were different, the qualitative conclusions were not affected.

The principal message of table 2 is that SRIRL was a common feature in the interwar period.[11] Of the 10 industries in the sample, only two (petroleum refining and leather) have estimated values of β less than one. For each of the eight industries with estimated values of β greater than one, the difference between the estimated β and labor's share in value added, shown in table 1, is highly statistically significant. The finding of interwar SRIRL does not depend on the inclusion or exclusion of the 1920s: The estimates from the full interwar sample and from the 1929–39 subsample are quite close.

Another striking feature of table 2 is the similarity of the estimates between the interwar and postwar sample periods. Despite obvious differences in the economic environments of the two periods, important product and process innovations, and an imperfect match in industry definitions, the correlation between the full interwar and postwar estimates of industry β's is .90; the rank correlation is .82. It should also be noted that the unweighted mean of the interwar β's is slightly higher than that of the postwar era, 1.07 to 0.96.

We conclude overall that there is strong evidence for SRIRL in interwar manufacturing data and that there is little difference in this regard between the Depression decade and the interwar sample as a whole, or between the interwar period and the postwar period.

V. The Technological Shocks Hypothesis

We now consider how our findings for the interwar period bear on the three alternative explanations for the general SRIRL phenomenon outlined in Section II, beginning with the technological shocks hypothesis.

We would argue that the finding of SRIRL (estimated $\beta > 1$) in the interwar period is a serious problem for the technological shocks explanation of SRIRL, as advocated by the real business cycle school. Our reasoning is as follows: No one, including the real business cycle school, seriously maintains that the Great Depression was caused primarily by technological shocks to industry production functions.[12] To

[11] A similar result was found by Bernanke and Powell (1986).

[12] See, e.g., Prescott (1986*a*, p. 29). Bernstein (1987) suggests that, while the interwar period as a whole was characterized by considerable and widespread innovative activity, technical change in the Depression decade itself was restricted to a small number of industries. Parkinson (1990) reviews the available material on technical change in the specific industries studied here and concludes that while innovations certainly occurred during the Depression, their scope was relatively modest. This is consistent with the low rate of gross investment during the 1930s. In any case, *negative* technological shocks would be needed to explain the sharp falls in output and employment that occurred during the Depression.

the extent that the large fluctuations in output and employment that occurred were due to other types of shocks (e.g., shocks to aggregate demand or to factor supplies), under the maintained real business cycle assumptions, SRIRL should not have been manifest in the Depression period. Instead, diminishing returns to labor should have been observed. But as we have seen, SRIRL was at least as strong in the interwar period as in the postwar period, contradicting this basic real business cycle prediction.

This point can be restated in terms of the discussion of Section II. Recall that, under the technological shocks hypothesis, the bias in the estimate of β is proportional to σ_ϵ/σ_n, where σ_ϵ and σ_n are the standard deviations of the growth rates of technology and labor input, respectively.[13] We can observe directly from the data that the standard deviation of quarterly labor input growth σ_n was on the order of two to three times larger in the interwar data than in the postwar data, depending on the industry. Thus, under the assumption that the true β's were similar in the two eras (and labor shares in fact have not changed very much), the technological shocks hypothesis can explain the finding of interwar SRIRL only by asserting that the standard deviation of technological change σ_ϵ also was two to three times larger in the interwar data than in the postwar data. This amounts to explaining the Depression by a large exogenous increase in technological variability, which we believe is historically implausible.

A possible real business cycle rebuttal is that many of the real shocks that contributed to the Depression—including shocks to the payments and credit systems, political instability in Europe, tariff wars, falling agricultural prices, sectoral "imbalances" caused by World War I, and New Deal policies affecting price and wage setting—might be construed broadly as "productivity shocks," if not technological shocks in the literal sense. Under this interpretation, an explanation of interwar SRIRL can be offered that is in the spirit of the real business cycle explanation for postwar SRIRL, namely, that other types of real shocks played the role of more narrowly defined technological shocks in the interwar period.

To be clear, we should emphasize that we do not deny that real shocks were important for the Depression (obviously they were) or even that it might be possible to construct an equilibrium model that

[13] The factor of proportionality is $\rho_{n\epsilon}$, the correlation of labor supply response to technology shocks. The magnitude of this correlation depends on the willingness of workers to substitute intertemporally and on the expected persistence of productivity shocks, with less persistent shocks causing a stronger response. Although we cannot say what workers believed ex ante, the Depression of course turned out to be an extremely persistent shock, so that if anything $\rho_{n\epsilon}$ should have been lower in the interwar period than in the postwar period. A lower value of $\rho_{n\epsilon}$ would make it even more difficult for the technology shocks hypothesis to explain the presence of SRIRL in the interwar data.

explains the Depression as a response to those shocks. The issue here is instead whether the real shocks that occurred during the Depression can explain the observation of SRIRL in a way consistent with the real business cycle approach. *To do so, it would be necessary for these shocks to have had their effects primarily by changing the amount of industry outputs producible by given levels of capital and labor inputs;* that is, they would have to have been "ϵ-like" shocks, where ϵ is the error term in (2). Again, to the extent that real shocks had their effects in other ways—by changing labor supply, the structure of product or labor markets, or the expected marginal productivity of new capital goods, for example—they should have induced countercyclical rather than procyclical variation in labor productivity.[14] In terms of the econometric discussion, real shocks that raise σ_n but not σ_ϵ will not lead us to find SRIRL in the data.

Might the real shocks that occurred during the 1930s have been the functional equivalents of technological shocks to industry production functions? One can think of some possible stories: For example, it might be conjectured that trade restrictions affected the cost or availability of intermediate inputs; substitution away from intermediate inputs toward labor would show up as negative productivity shocks in our empirical analysis, given that we must measure output as total production rather than as value added. However, while this is a theoretical possibility, the direct evidence for a disruptive effect of trade restrictions is weak: In particular, the Smoot-Hawley tariff of 1930 primarily affected imports of agricultural goods and finished manufactures, not intermediates (Eichengreen 1986). Indeed, because of the worldwide glut of raw materials and commodities, the real prices of most imported intermediates (inclusive of tariffs) fell during the Depression.

Another potential source of not strictly technological productivity shocks is the breakdown in the early 1930s of the monetary and financial system, which many writers on the Depression have argued was important. In principle, money and credit can be thought of as substitutes for other inputs, implying that disturbances to the payments and credit mechanisms might reduce labor productivity.[15] However, Bernanke (1983), citing Lutz (1945), argued that in the

[14] In particular, some existing classical explanations of the Depression would not in general be consistent with both diminishing returns and the observation of SRIRL. Consider, e.g., the explanation of Lucas and Rapping (1969), which argues that workers misperceived the real wage and thus reduced labor supply. Under maintained real business cycle assumptions, this induced movement *back along* the diminishing returns production function should have led to countercyclical labor productivity rather than procyclical productivity as observed.

[15] King and Plosser (1984) formalize this idea.

United States most larger firms (which would make up an important share of output and employment in our sample) entered the 1930s with more than sufficient cash and liquid reserves to finance working capital needs;[16] a similar conclusion was reached by Hunter (1982). On this basis, Bernanke concluded that, at least in the United States, financial effects must have worked to a greater extent by reducing aggregate demand, including the demand for new investment, rather than by affecting the quantity of output producible with given quantities of capital and labor inputs. To the degree that credit and monetary factors affected the demand for rather than the supply of current output, under the maintained real business cycle assumptions they should have induced diminishing rather than increasing returns to labor.

We conclude that it is unlikely that the economic shocks of the interwar period entered industry production functions in the way required by the broad version of the technological shocks hypothesis. But even if future research should identify shocks of this form, there is an additional problem for the "real but not strictly technological" shocks story. This problem is how to explain the high cross-sectional (across industry) correlation of the estimated β's between the interwar and postwar sample periods. To rationalize this similarity, it would have to be the case that the real shocks hitting individual industrial production functions in the interwar period accounted for about the same percentage of employment variation *in each industry* as genuine technological shocks hitting industrial production functions did in the postwar period. In other words, even though the shocks hitting production functions in the interwar period (e.g., credit shocks) were presumably of a nature qualitatively different from the corresponding shocks in the postwar period, the real business cycle hypothesis requires that the bias term for each industry, $\rho_{n\epsilon}\sigma_\epsilon/\sigma_n$, was nevertheless approximately the same before and after the war. This would be extremely coincidental.

Our discussion so far has concerned the interpretation of OLS estimates of industry production functions. A more direct way to test the technological shocks hypothesis is to reestimate the production functions using instrumental variables. If our instruments are correlated with industry employment and output but uncorrelated with industry technological shocks, and if the technological shocks hypothesis is true, then instrumental variables estimates of the labor input coefficient β should be much lower (closer to labor's share) than the OLS estimates.

[16] Lutz's sample of large firms included the major firms in (among other industries) automobiles, iron and steel, building materials, chemicals, petroleum, and textiles, all of which overlap to some degree with industries used in our study.

Instrumental variables estimates of β for each industry for the 1924–39 and 1929–39 sample periods are reported in table 2, columns 3 and 4. The instruments used to obtain the reported estimates were the current values and one lag each of real government expenditure, the currency/deposit ratio, and the real deposits of failed banks, all in log differences.[17] Our choice of these variables is consistent with what we take to be the dominant view among economic historians, that policy mistakes—including mismanagement of the gold standard, failure to defend the banking system and the money supply, and procyclical fiscal policy—were major causes of the Great Depression in the United States. These instruments surely are not strongly exogenous, but they plausibly have very weak contemporaneous correlation with shocks to industrial production functions. Robust standard errors calculated by the method of Wooldridge (1989) are reported; again, these were generally quite similar to the conventional standard errors.

As can be seen from table 2, the instrumental variables estimates of β differ relatively little from the OLS estimates.[18] This was also true when both broader and narrower instrument sets were used, as an earlier version of the paper reported. Indeed, Hausman specification tests comparing the OLS and instrumental variables estimates almost never can reject the hypothesis that the OLS regressions are not misspecified; for the instrumental variables estimates reported in table 2, no misspecification could be rejected at the 10 percent level only for the petroleum refining industry, which was not one of the eight SRIRL industries. Once again, we find little support for the technological shocks hypothesis in the interwar data.[19]

[17] Data sources for instrumental variables are as follows: Government spending data come from Firestone (1960). The currency/deposit ratio is calculated from Friedman and Schwartz (1963). Deposits of failed banks come from the *Federal Reserve Bulletin* and are deflated by the consumer price index due to Sayre (1948).

[18] Indeed in a number of industries the instrumental variables estimates are larger than the OLS estimates. This contradicts the implication of the technology shocks hypothesis that the OLS bias should be positive, suggesting instead the presence of some factor such as classical measurement error. (We thank Jerry Hausman for pointing this out to us.)

[19] Overfitting in the first stage, a potential pitfall in the comparison of OLS and instrumental variables estimates, is not an issue here: For the latter, first-stage R^2's were in an intermediate range (usually between .4 and .6), and no misspecification was found even when more minimal sets of instruments were used. Also, in this application, the Hausman test can be implemented by regressing labor input growth against the instruments, then entering the fitted and residual values from this regression separately in a regression for output growth; the Hausman test amounts to a test of whether the estimated coefficients on fitted and residual labor input growth in the second-stage output growth regression are the same. When we implemented the test this way, we found the estimated coefficients on fitted and residual labor input growth to be individually highly significant and very similar in magnitude, a result that would not be expected if overfitting were a problem.

VI. Increasing Returns versus Labor Hoarding

If we put aside technological shocks as an explanation for SRIRL, we are still left with the two possibilities of increasing returns and labor hoarding. In trying to discriminate between these explanations, we relied on the observation that, if the increasing returns hypothesis is true, then the production function relationship (2) is well specified; but if the labor hoarding view is true, equation (2) suffers from an omitted variable problem (compare eqq. [2] and [3]) since it ignores the rate of labor utilization. This suggests testing the increasing returns hypothesis against the labor hoarding alternative by checking whether variables that are "fundamentally" extraneous, but that might be correlated with utilization rates, can be statistically excluded from estimated production functions.

As a first test of this type, for each industry we regressed output growth on labor input growth, a constant, seasonal dummies, and a set of aggregate business cycle indicators. As we have just argued, if there are true increasing returns, industry labor input should be a "sufficient statistic" for industry output, and the cyclical indicators should not appear in the production function.[20] On the other hand, if there is labor hoarding and the cyclical indicators are sufficiently correlated with the omitted utilization term, the cyclical indicators will enter the estimated production function significantly. Further, to the extent that the cyclical indicators are good proxies for utilization rates, the estimated coefficients on labor input should be closer to the true production function coefficients (thus lower in magnitude, presumably) when the cyclical indicators are included.

There are several reasons to think that cyclical indicators will be correlated with unobserved variations in utilization if labor hoarding is in fact important. For example, suppose that fluctuations in industry demand due to changes in cyclical conditions have different persistence properties than changes in industry demand due to idiosyncratic sectoral shocks. Then labor-hoarding firms will optimally respond to cyclical and sectoral demand shocks with different combinations of employment and utilization adjustment, and aggregate cyclical indicators will contain information about industry utilization rates. Another possibility is that an industry's costs of adjusting the labor force depend on aggregate labor market conditions; again, in general, this would tend to create a correlation between cyclical indicators and industry labor utilization rates.[21]

[20] If one assumes that the increasing returns are internal to the industry (see below). This argument would also be complicated by the presence of aggregate productivity shocks. At this point we maintain the hypothesis that productivity shocks can be neglected in the interwar period.

[21] We thank the referee for this second point.

TABLE 3

ESTIMATES OF THE LABOR INPUT COEFFICIENT WHEN BUSINESS CYCLE INDICATORS ARE INCLUDED

	Cyclical Indicators	
Industry	List 1 (1)	List 2 (2)
Steel	1.56**	.54**
	(.13)	(.30)
Lumber	1.16	1.04
	(.06)	(.13)
Autos	1.24	1.21
	(.20)	(.26)
Petroleum	.26	.06**
	(.13)	(.07)
Textiles	.95	.61**
	(.12)	(.16)
Leather	.58	.44
	(.12)	(.15)
Rubber	1.16**	1.12**
	(.06)	(.15)
Pulp	1.14	.78*
	(.13)	(.21)
Stone, clay, glass	1.21	.96
	(.06)	(.33)
Nonferrous metals	1.53**	.52*
	(.05)	(.47)

NOTE.—Data are quarterly. Standard errors are in parentheses. All regressions include a constant and three seasonal dummy variables. The sample period for all regressions is 1924:1–1939:4 except for stone, clay, and glass and nonferrous metals, for which it is 1933:1–1939:4. Cyclical indicator list 1 includes the current value and one lagged value of the log differences of real government expenditure, the currency/deposit ratio, and real deposits of failed banks. Indicator list 2 is list 1 plus the current and first lagged values of the log differences of the consumer price index and aggregate manufacturing production.

* The null hypothesis that all cyclical indicators can be excluded is rejected at the 5 percent significance level.

** The null hypothesis is rejected at the 1 percent significance level.

The results of this exercise are contained in table 3. Two sets of cyclical indicators were used. Set 1 (corresponding to col. 1 of the table) included current and once-lagged growth rates of real government spending, the currency/deposit ratio, and the deposits of failed banks; these are the same variables used as instruments in table 2. Set 2 (corresponding to col. 2) included all variables in set 1 plus current and once-lagged growth rates of the consumer price index and the Federal Reserve aggregate industrial production index. The numbers reported in the two columns of table 3 are the estimated labor input coefficients when cyclical indicators were included, with Wooldridge standard errors in parentheses. The regressions in which joint exclusion of the cyclical indicators from the production function can be rejected at conventional significance levels are indicated by asterisks.

The results depend on which set of cyclical indicators is used. With the narrower set, set 1, exclusion of the indicators from the production function is rejected in only three of the 10 industries (albeit at the 1 percent significance level in each case). Further, comparing the results from set 1 with those reported in table 2, column 1, we see that the estimated values of the labor input coefficient are not systematically lowered when the indicators in set 1 are included, as would be expected if there is labor hoarding and the cyclical indicators proxy for utilization rates. In contrast, with the broader set of indicators, set 2, the cyclical indicators cannot be excluded from the production function in six of the 10 industries (four at the 1 percent significance level); in each of these industries, the estimated value of the labor input coefficient is reduced, as the labor hoarding view predicts.[22]

The results seem moderately favorable to labor hoarding, at least when the broader set of cyclical indicators is used. However, a rationalization of the results of table 3 that does not rely on labor hoarding is that the appearance of cyclical indicators in industry production functions is evidence of *external* (to the industry) increasing returns. Indeed, this is how Caballero and Lyons (1989) interpreted a very similar set of results for postwar data. We find it hard to imagine external economies large enough to account for our results, however, and are thus more inclined to favor the labor hoarding interpretation of our estimates.

As a second test of increasing returns versus labor hoarding, we examined the dynamic response of industry labor input to changes in industry production by regressing current labor input growth on current and lagged output growth, a constant, and seasonal dummies. If there are costs of adjusting labor input, as required by our specification of the labor hoarding hypothesis, firms are likely to respond to changes in demand for output by increasing effort requirements in the short run and adjusting measured labor input only gradually.[23] In an industry without adjustment costs, in contrast, labor input should adjust immediately when there is a change in demand and should therefore depend only on current and not lagged output. This test is similar in spirit to the last one, in that again we are testing

[22] When only the contemporaneous growth rate of aggregate industrial production was added to the production function equation, it entered significantly in four industries.

[23] Gradual adjustment would be expected if there was uncertainty about the permanence of the demand change or if costs of adjustment are convex.

TABLE 4

ELASTICITY OF TOTAL LABOR INPUT GROWTH WITH RESPECT TO CURRENT AND LAGGED OUTPUT GROWTH

	Ordinary Least Squares		Instrumental Variables	
Industry	q_t	q_{t-1}	q_t	q_{t-1}
Steel	.46	.20	.48	.31
	(.02)	(.01)	(.04)	(.04)
Lumber	.74	.11	.85	.13
	(.07)	(.03)	(.06)	(.07)
Autos	.52	−.04	.69	.01
	(.06)	(.03)	(.10)	(.09)
Petroleum	.35	.13	.79	.21
	(.09)	(.13)	(.45)	(.24)
Textiles	.48	.03	.60	.10
	(.06)	(.08)	(.11)	(.09)
Leather	.78	.14	1.21	.37
	(.15)	(.10)	(.15)	(.19)
Rubber	.61	.20	.62	.31
	(.04)	(.06)	(.04)	(.04)
Pulp	.66	.16	.81	.18
	(.06)	(.05)	(.08)	(.08)
Stone, clay, glass	.73	.18	.80	.20
	(.03)	(.04)	(.05)	(.08)
Nonferrous metals	.63	−.01	.66	.02
	(.04)	(.04)	(.03)	(.10)

NOTE.—Data are quarterly. Standard errors are in parentheses. All regressions include a constant and three seasonal dummy variables. The sample period for both regressions is 1924:1–1939:4 except for stone, clay, and glass and nonferrous metals, for which it is 1933:1–1939:4. The instruments used in the instrumental variables regression are the current value and one lagged value of the log differences of real government expenditure, the currency/deposit ratio, and real deposits of failed banks.

for labor hoarding by checking whether a variable that is "extraneous," but that is potentially informative about utilization rates, can be statistically excluded from the contemporaneous relationship between output and labor input; in this case the extraneous variable is lagged output growth.

For each industry and for the full interwar sample period, table 4 reports the estimated coefficients on current and lagged output growth, with Wooldridge standard errors in parentheses. Both OLS and instrumental variables estimates are presented, with the instruments in the latter regressions the same as those used in table 2. We interpret a significant estimated coefficient on lagged output in this regression as evidence for lagged adjustment of labor input and thus for labor hoarding. In the OLS estimates, five of the eight SRIRL industries have coefficients on lagged output that are economically and statistically significant; in the instrumental variables estimates, the statistical significance of one of these five industry coefficients becomes marginal. Since the data are quarterly, the estimates thus suggest a significant lag in employment adjustment for a majority of the SRIRL industries, which favors the labor hoarding hypothesis. On the other hand, the correlation between industries exhibiting lagged adjustment of labor input to output and those for which cyclical indicators enter the production function is not particularly good: Only three SRIRL industries (steel, rubber, and stone, clay, and glass) pass both tests for labor hoarding.

VII. Conclusion

This paper has documented that manufacturing industries in the interwar period exhibited short-run increasing returns to labor or procyclical labor productivity, to a degree very similar to what has been observed in the postwar period; indeed, the industry-by-industry pattern of SRIRL is very similar between the two periods. We have argued that this finding is troublesome for the technology shocks explanation of procyclical productivity (and thus for the real business cycle hypothesis). To explain interwar SRIRL in a way consistent with the technology shocks hypothesis, it must be argued either that changes in industrial technologies caused the Depression or that the real (nontechnological) shocks of the 1930s just happened to generate a cross-sectional pattern of SRIRL very similar to that created by true technological shocks in the postwar period. We find these arguments to be implausible. Additional evidence against the technological shocks hypothesis is provided by instrumental variables estimates of industry production functions, which are very similar to the OLS estimates.

While we rule out technological shocks as an explanation for interwar SRIRL, the distinction between industries for which labor hoarding is the key factor and those for which increasing returns are dominant is less clear-cut. We devised a set of simple statistical tests that treat increasing returns as the null hypothesis and labor hoarding as the alternative; unfortunately, these tests do not always reject increasing returns or always fail to reject it. It may be that both explanations have some validity, with weights that differ by industry.

It may also be that our inconclusive results are due to the use of a nonexhaustive set of explanations. An alternative explanation of SRIRL that we have not explicitly considered (primarily because it does not fit conveniently into our Cobb-Douglas organizing framework) is the overhead labor hypothesis. This hypothesis (which may be taken as an alternative rationalization of labor hoarding) assumes that there is a fixed group of workers whose presence is necessary for the firm to produce any positive amount of output. Over a range of production levels, which depends on the number of overhead workers and the rate at which returns to variable labor input diminish, the presence of overhead workers can create the illusion of increasing returns. Exploring this possibility is a useful direction for future research.[24]

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[24] If overhead workers are primarily nonproduction workers, then the overhead labor hypothesis is consistent with the observation that the ratio of nonproduction to production workers rose during the Depression (U.S. Bureau of Labor Statistics 1957). However, a key issue is whether a significant amount of overhead labor is included in the category of production workers; if not, this hypothesis cannot explain the results of this paper since we measure labor input by production workers only.

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