Empirical Economics (2005) 30:151–169
DOI 10.1007/s00181-004-0226-4

EMPIRICAL ECONOMICS

Dynamic employment adjustments over business cycles

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First version received: March 2002/Final version received: November 2003

Abstract. This paper uses U.S. monthly industrial production employment data between 1964 and 2000 to examine the dynamic labor adjustments of production workers and nonproduction workers in both the short and long-run. The results from the short-run analysis show that the dynamic adjustment of production workers is consistent with business cycles. However, the adjustment of nonproduction workers is relatively fixed, lags behind the shocks over business cycle changes, and exhibits the quasi-fixed factor property. In the long-run, we found that nonproduction workers and production workers are cointegrated indicating that the two series are in long-run equilibrium.

Key words: Employment adjustment, business cycles, quasi-fixed labor

JEL classification: B320, J210, J500

1. Introduction

As Becker (1993) has documented, both theoretically and empirically, investing in human capital has been shown to be an important factor in economic growth. An interesting offshoot of this literature is whether this human capital approach has implications with respect to how labor adjusts to economic cycles. When one considers the two main factors of production, labor and capital, labor is generally considered to be the variable

We would like to thank James McClure, participants in the Economics Department seminar series at Ball State University, and an anonymous referee for their comments and suggestions.

factor in the short-run while capital is thought to be fixed. Thus, labor is more likely to adjust to economic shocks than is capital. On the other hand, Oi (1962) suggested that labor has some quasi-fixed properties. Focusing on hiring and training costs, Oi proposed that the demands for all variable factors will not be decreased in the same proportion when a firm is faced with a decline in product demand (Oi, p. 538). Since Oi's "fixed employment cost" theory of labor adjustment, many theoretical and empirical articles have studied this simple hypothesis. For example, Okun (1981) considers labor movements in different pools of labor with a "toll" model, where each pool of labor involves certain implicit costs to enter. Therefore, firms will adjust different kinds of labor based on how much of the toll they have yet to accumulate. Okun also suggested that labor adjustment to negative demand shocks cannot drop below a threshold level since labor and capital are complements. For example, a minimum level of labor is needed in order to run a firm's capital equipment.

The relative fixity in labor employment has several implications. Oi suggested that wage and unemployment differentials may result from the quasi-fixed property of labor employment. Since nonproduction workers are adjusted more slowly than production workers, it is expected that the wages of nonproduction workers are higher. Furthermore, unemployment rates will also be different for different occupations. This type of labor adjustment, explained by Oi, is similar to the "labor hoarding" models of Burnside and Eichenbaum (1996), Burnside et al. (1993), and Hansen (1985).

Since several models of the dynamic adjustment of labor are based on Oi's, it is useful to reproduce his model here. Suppose the adjustment of employment at time t, E_t, is represented by

$$E_t - E_{t-1} = k(E_t^* - E_{t-1}), \tag{1}$$

where E_t^* is the desired rate of employment and k represents the speed of adjustment. Assume the desired rate of employment depends on output, X_t, such that

$$E_t^* = \alpha + \beta X_t \tag{2}$$

Substituting (2) into (1) yields the equation $E_t = f(X_t, E_{t-1})$ for a linear regression model. The estimated coefficient of E_{t-1} measures the adjustment speed of employment. To test the quasi-fixed property of labor employment, consider two types of employment: production workers (P_t) and nonproduction workers (N_t). The regression models used by Oi are

$$P_t = a_0 k_P + a_1 k_P X_t + (1 - k_P) P_{t-1} + \varepsilon_{Pt}, \tag{3}$$

$$N_t = b_0 k_N + b_1 k_N X_t + (1 - k_N) N_{t-1} + \varepsilon_{Nt}, \tag{4}$$

where k_P is the coefficient of adjustment for production workers and k_N is the coefficient of adjustment for nonproduction workers. Using the manufacturing sector for employment and industrial production for output, Oi's results show $k_P = 0.6682$ and $k_N = 0.4389$ with standard errors of 0.11 and 0.134, respectively. Since the coefficient of adjustment for nonproduction workers is significantly smaller than that for production workers,

he concludes that the adjustment of nonproduction workers is slower than the adjustment of production workers. Hence, the evidence of a quasi-fixed property is found. An extension of this model is to include dynamic structures for employment and output. Most of this literature is summarized in Hamermesh (1993).

The major problem in this type of modeling lies in the time series properties of the employment and output series. As argued by Oi (p. 550), his empirical study of Eqs. (3) and (4) is confined to the prewar period, 1920–1939, "because of a strong secular trend in employment of nonproduction workers during the postwar period that destroyed the validity of the demand relationship." Therefore, if postwar data are to be used, it is necessary to examine the time series properties of labor employment.

Annual data of total employment between 1890 and 1970 and industrial production (output) between 1860 and 1970 are two of the fourteen series in Nelson and Plosser's (1982) influential empirical study. They found that these two series are nonstationary with unit roots. This finding of nonstationarity has two implications with respect to Oi's labor adjustment model. First, the employment of production workers and nonproduction workers may be nonstationary with unit roots as well. If P_t and N_t have unit roots, the statistical properties of the estimated coefficients of P_{t-1} and N_{t-1} in Eqs. (3) and (4) are difficult to determine. Therefore, there is no way to compare the adjustment speeds between production workers and nonproduction workers using this model. Second, the regressions of Eqs. (3) and (4) involve two nonstationary integrated processes, employment and output. When both dependent and independent variables are nonstationary, the *spurious regression* problem may occur (Granger and Newbold 1974). This spurious regression problem leads to biased statistical inferences. Although cointegration analysis (Engle and Granger 1987) can be applied to these integrated processes, cointegration analysis is only suitable for long run analysis. Therefore, it is inconsistent with the short run analysis in Oi's model.

This paper alleviates these problems by applying three econometric techniques to examine the dynamic adjustments of labor employment. We use dummy variable regressions and Granger causality tests to test the quasi-fixed factor hypothesis of labor employment by comparing the dynamic adjustments of production workers and nonproduction workers in the short-run, and use cointegration to check if production workers and nonproduction workers are moving together in the long-run. The next section presents the econometric models and empirical results, while the last section concludes the paper.

2. Econometric methods and empirical results

We use U.S. monthly employment postwar data between 1947 and 2000 to estimate the dynamic adjustments of labor employment. Because the adjustment characteristics may vary in different types of industries, we consider employment data for five sectors from three industrial categories. The first category contains only overall industrial production. The second category includes two subdivisions of industrial production, the nonmanufacturing and the manufacturing sectors. The third category includes two

subdivisions of the manufacturing sector, the durable and nondurable goods sectors.[1] As in Oi's empirical work, total employment in each sector is divided into production and nonproduction workers. Oi argued that the higher wages of nonproduction workers is an indication of high fixed employment costs and the quasi–fixed property. Therefore, we follow Oi's lead and divide employment into production and nonproduction workers.[2] Figure 1 shows the graphs of total employment, production and nonproduction workers for each of five sectors. The graphs indicate employment for both industrial production and nonmanufacturing sectors follow a strong deterministic trend, while employment in the other three sectors appear to possess cyclical movements. To statistically determine the time series properties of these series, we conduct unit root test on these series in the next subsection.

2.1. Integrated processes of unit roots for employment and output

Since Nelson and Plosser's (1982) study on the stationarity of macroeconomic time series with the augmented Dickey-Fuller test (ADF) (Dickey and Fuller 1979, 1981), several new unit root tests have been proposed to determine the stationarity of time series data. A survey of these unit root tests can be found in Maddala and Kim (1998). It is not surprising that different unit root tests often yield different conclusions. For example, Choi (1994) found that employment is still difference stationary with a unit root; DeJong and Whiteman (1991) and Leybourne (1995) found that employment is trend-stationary without a unit root; and Phillips (1991) and Kwiatkowski et al. (1992) were unable to draw a clear conclusion about the unit root for employment. Although there is no unique "best" unit root test, we use Elliott et al. (1996) modified Dicky-Fuller (DF-GLS) test along with the lag selection criterion of Ng and Perron (2001). Elliott, Rothenberg, and Stock found that the power of the augmented Dickey-Fuller test can be significantly improved by a GLS detrending method, while Ng and Perron show that the size distortion found in most unit root tests can be corrected by using a "modified AIC" method to select the number of lags in formulating unit root tests.

Table 1 shows the results of the DF-GLS tests for the levels and first differences of the twenty-one series. These series include total employment (E), production workers (P), nonproduction workers (N), and the ratios of nonproduction workers to production workers (N/P) for each of the five sectors, as well as the industrial production index. The N/P ratio is used to compare the

[1] The share of employment in the nonmanufacturing sectors to industrial production's total employment averages 75% over the sample period, while the share of employment in the durable sector to the manufacturing sector is 57%. This hierarchical classification may present aggregation issues. This suggests one should concentrate on the differences between nonmanufacturing and manufacturing sectors, and the differences between durable and nondurable goods sectors.

[2] Hamermesh (1993, p. 278) suggests that "there is a substantial overlap in the skill distributions of production and nonproduction workers." Since the time series data with labor separated by production and nonproduction workers can be easily obtained from Bureau of Labor Statistics, we don't consider the separation of skill and unskilled workers. All data in this paper are obtained from DRI Basic Economics Database.

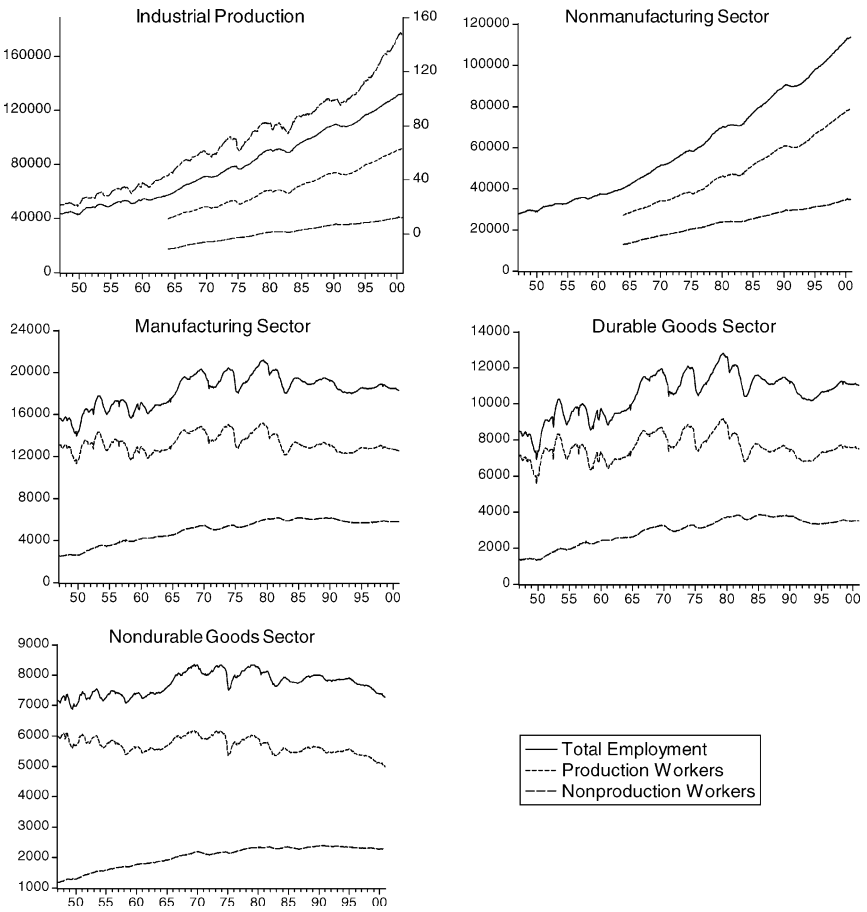

Fig. 1. Employment and the industrial production index
Notes: The numbers on the horizontal axis are years. The numbers on the left axis are the numbers of workers in thousands. Except for industrial production, the top line is total employment, then followed by production workers and nonproduction workers. For the industrial production graph, the top line is the industrial production index with the index number on the right axis. The next three lines are the three employment series.

relative changes in nonproduction and production workers, and the industrial production index is a proxy for output. Based on the statistics for the levels in the first two columns, the unit root cannot be rejected for all series, except for manufacturing production workers. For this series, the unit root is rejected only when the constant is included. We can conclude that this series may be stationary, but all other twenty series are nonstationary with unit roots.

To determine if each series is integrated of order one or two, we perform unit root tests for the first differences under two models – one without a constant and one with a constant. These results are reported in columns 3 and 4. Among these twenty-one series, sixteen series show significance under both models; one series shows insignificance under both models; and four series show significance under one model and insignificance under the other model. We can conclude that sixteen series cannot be integrated of order two since

Table 1. DF-GLS unit root tests

		Level		First Difference	
		C	C, T	NC[a]	C
IP	E	3.56	−0.99	−2.78*	−5.87*
	P	2.15	−2.26	−2.89*	−2.46*
	N	0.94	−1.79	−1.64	−3.09*
	N/P	−0.69	−0.58	−4.35*	−1.40
Nonmanufacturing	E	2.95	−0.27	−2.19*	−3.21*
	P	2.01	−1.00	−1.80	−1.74
	N	1.00	−2.34	1.50	−3.22*
	N/P	−0.66	−0.70	−3.77*	−1.0
Manufacturing	E	−0.61	−1.56	−7.27*	−7.18*
	P	−2.50*	−2.52	−7.68*	−7.21*
	N	1.03	−0.23	−4.08*	−2.88*
	N/P	1.44	−0.83	−6.22*	−2.99*
Durable	E	−0.53	−1.74	−7.35*	−6.01*
	P	−1.93	−2.39	−7.84*	−3.50*
	N	0.93	−0.48	−4.15*	−3.45*
	N/P	0.86	−1.00	−6.38*	−2.73*
Nondurable	E	−0.86	−0.96	−9.07*	−2.77*
	P	0.10	−1.96	−9.36*	−3.23*
	N	1.20	0.08	−4.28*	−2.05*
	N/P	2.19	−1.07	−4.41*	−3.96*
The industrial production index		3.62	−0.72	−3.80*	−5.72*

Notes: "E" indicates total employment; "P" is production workers; and "N" is nonproduction workers. For the column titles, "C", "C, T", and "NC", indicate the unit root tests with the intercept, with both the intercept and the trend, and without intercept, respectively. All data are in monthly frequency. Data of manufacturing, durable, and nondurable are from 1947 to 2000. The rest data are from 1964 to 2000. The critical values for the model with the intercept and the model with both the intercept and the trend with 5% significance level are −1.94 and −2.89, respectively. Asterisks indicate the rejection of the unit root at the 5% level.

[a] For the model without the intercept, we use the augmented Dickey-Fuller test since DF-GLS is not applicable in this case. The critical value for this ADF test is −1.94.

the unit root hypothesis is rejected for the first differences. These sixteen series include the industrial production index, all series in the manufacturing, durable and nondurable goods sectors, and three series in both the industrial production and nonmanufacturing sectors. The one series that shows insignificance under both models is nonmanufacturing production workers. When the ADF unit root test is applied to the second order differences of this series, the test statistic is −42.08. The unit root hypothesis is rejected, and this series is integrated of order two. The remaining four series which are rejected, under one of the models, are nonproduction workers and N/P ratios in two sectors, industrial production and nonmanufacturing sectors. The order of integration for each of these four series depends on the model considered. To determine which model is appropriate, we begin the unit root test with a general model, such that the constant is included in the unit root tests for the first differences of these four series. When the constant is significant, we use that model; when the constant is not significant, we use the model without the constant. The constant is found to be insignificant for N/P ratios, but significant for nonproduction workers in these two sectors. Thus, we use the model without the constant for N/P ratios, and the model with the constant

for nonproduction workers in these two sectors. Under each chosen model, the unit root statistic is significant for each series. Therefore, these four series are integrated of order one.

In summary, of the twenty-one series examined, one series may be stationary, one series may be integrated of order two, and all other nineteen series are integrated of order one. We can conclude that the output series and almost all employment series are nonstationary. This suggests that the dynamic models based on Oi are inappropriate for postwar data. To address this problem, the next subsections apply three different modeling approaches.

2.2. Labor employment adjustment in different stages of business cycles

To compare the relative adjustments of nonproduction and production workers, we consider how employment in the five sectors vary over the different stages of the downward and upward phases of the business cycle. In general, when an economy is in a downward (upward) phase of a business cycle, changes in employment are negative (positive). For nonproduction workers to be a quasi-fixed factor with respect to production workers, two possible results could be observed. First, the percentage changes in nonproduction workers may be smaller than the percentage changes of production workers in different stages of the business cycle. Second, a lagged adjustment of nonproduction workers may occur. There will be a lagged adjustment if employment of nonproduction workers stays the same in the early stages of a downward (upward) phase of the business cycle and starts to decrease (increase) in the latter stages of a downward (upward) phase. Therefore, to examine the possibility that nonproduction workers exhibit the quasi-fixed property, it is necessary to further divide each downward and upward phase into several different stages.

Based on the tuning points of U.S. business cycles dated by the National Bureau of Economic Research, we define eight different stages for any given business cycle by dividing the downward phases and upward phases of each cycle into four equal parts.[3] The four stages of the downward phase are denoted by D1, D2, D3, and D4, and the four stages of the upward phase are denoted by U1, U2, U3, and U4. Then, each month is assigned to one of these dummy variables for the monthly data between 1964 and 2000. The general form of the dummy variable regression to estimate the mean changes of employment in the different stages of business cycles is

$$\Delta Y_t = \alpha_1 D1_t + \alpha_2 D2_t + \alpha_3 D3_t + \alpha_4 D4_t + \alpha_5 U1_t + \alpha_6 U2_t + \alpha_7 U3_t + \alpha_8 U4_t + \varepsilon_t, \tag{5}$$

where the dependent variable is the change in actual employment data. The estimates of the α's measure the mean changes in employment in the different stages of business cycles. If no lagged adjustments occur, the coefficients of D1, D2, D3, and D4 should all be negative and the coefficients of U1, U2, U3, and U4 should all be positive. If there are lagged adjustments, then the

[3] While dividing each upward and downward cycle, we first tried two stages in each upward and downward cycle. Then we tried four stages. Since there are relatively few observations for the downward cycles with four stages, we stopped at four-stage division.

coefficients of D1 and U1 (or D1 and D2 or U1 and U2) should be insignificant or the wrong sign.

This dummy variable regression has two advantages over those dynamic models based on Oi. First, the dependent variable in these dummy variable regressions is the change in employment instead of the level of employment. Since the unit root tests in the previous subsection show that almost all employment series are nonstationary with unit roots, regressions with the level of employment as the dependent variable lead to a problem with nonstationarity. On the other hand, a dummy variable regression with the change in employment as the dependent variable avoids this problem. Second, we use eight dummy variables as the independent variables in the regressions, whereas Oi uses an output variable (or industrial production) in Eqs. (3) and (4). Both approaches are structural models and are similar. One directly uses the information from business conditions to represent the different stages of the business cycle, while the other uses output to approximate the equilibrium level of employment. The use of dummy variables not only avoids the problem of nonstationarity in the output series, but also the dummy variable regression is a type of nonlinear modeling.[4] The different dummy variables for the different stages of business cycles are used to capture the nonlinear relationship between employment adjustments and business cycles.

Table 2 presents the results for the dummy variable regressions with the dependent variables being the changes in total employment (ΔE), production workers (ΔP), nonproduction workers (ΔN), and the change in the ratio of nonproduction workers to production workers ($\Delta \frac{N}{P}$) for each sector. Three employment series for industrial production and the nonmanufacturing sectors have strong deterministic trends as shown in Fig. 1 and the unit root tests. To remove the trend in these six series, first differences are applied to the "detrended data" instead of the original data. The detrended data are the residuals from the regressions of these series on the constant and the trend. The detrended data are used to measure the deviation of the series from the long-run deterministic trend and are related to the short-run adjustment caused by business cycles. When unit root tests are applied to these six detrended series, all these six detrended series are also found to be integrated of order one. These test results are not reported here.

Table 2 shows that the estimated coefficients for the changes in total employment are close to the coefficients for the changes in production workers, but are very different from those for the changes in nonproduction workers.[5] For example, the coefficients for ΔE for industrial production in the

[4] Granger (1981, p.127) shows that the regression with the change in employment as dependent variable and the level of production as an independent variable is inappropriate when the change in employment is stationary and the level of production is integrated of order one. Instead, he suggests that it is more appropriate to use the change in output as an independent variable.

[5] In this section, the term "coefficients" refer to the coefficients of the dummy variables unless otherwise indicated. The problems of under-differencing and over-differencing may occur for the dummy variable regression. The series of nonmanufacturing production workers is found to be integrated of order two and the manufacturing production workers is stationary. When we check the autocorrelation, the first five autocorrelation coefficients for the first difference of nonmanufacturing production workers are 0.226, 0.382, 0.406, 0.273, and 0.309, and the first five coefficients for manufacturing production workers are 0.992, 0.977, 0.957, 0.933, and 0.906. The problems of under-differencing and over-differencing might be minor for these two series.

Table 2. Mean changes of employment in different stages of business cycles

	Downward phases				Upward phases				$\overline{R}^2$	DW
	D1	D2	D3	D4	U1	U2	U3	U4		
Observations	15	13	14	15	85	97	104	100		
Industrial production										
ΔE	−126*	−237*	−296*	−412*	43.71	86.87*	115.5*	45.76*	0.43	1.70
ΔP	−120*	−247*	−272*	−380*	38.58	63.09*	68.70*	14.33	0.41	1.87
ΔN	−26.04	−10.11	−44.5*	−52.5*	−15.3*	3.38	26.36*	11.02	0.10	1.83
Δ (N/P)	0.61	1.87*	1.54*	2.49*	−0.61*	−0.42*	−0.03	0.08	0.19	2.08
Nonmanufacturing sector										
ΔE	−68.8*	−120*	−148*	−177*	23.53	67.88*	83.79*	44.42*	0.24	1.82
ΔP	−72.6*	−145*	−150*	−180*	6.88	38.82*	39.22*	10.16	0.22	2.03
ΔN	−23.40	−1.67	−25.17	−24.67	−10.6*	1.81	17.32*	7.01	0.04	1.91
Δ (N/P)	0.24	1.46*	1.00*	1.44*	−0.44*	−0.43*	−0.07	−0.08	0.06	2.29
Manufacturing sector										
ΔE	−52.2*	−113*	−144*	−230*	25.24*	24.05*	36.74*	6.41	0.43	1.43
ΔP	−52.0*	−107*	−127*	−205*	27.49*	20.05*	25.27*	−0.04	0.40	1.59
ΔN	−0.20	−6.00	−16.9*	−25.4*	−2.25	4.00*	11.47*	6.45*	0.30	1.02
Δ (N/P)	1.47*	2.87*	2.65*	4.48*	−1.11*	−0.24	0.13	0.50*	0.29	1.90
Durable goods production										
ΔE	−38.2*	−79.8*	−107*	−176*	17.49*	20.46*	29.86*	5.54	0.39	1.60
ΔP	−37.3*	−75.5*	−92.1*	−156*	19.94*	16.88*	21.13*	0.95	0.35	1.80
ΔN	−0.93	−4.31	−14.9*	−19.8*	−2.45	3.59*	8.72*	4.59*	0.30	1.06
Δ (N/P)	1.78*	3.74*	3.19*	6.38*	−1.62*	−0.36	0.04	0.55*	0.25	2.10

Table 2. (Contd.)

	Downward phases				Upward phases				$\bar{R}^2$	DW
	D1	D2	D3	D4	U1	U2	U3	U4		
Nondurable goods production										
ΔE	−14.0*	−32.8*	−36.8*	−53.8*	7.75*	3.59	6.88*	0.87	0.30	1.35
ΔP	−14.9*	−31.1*	−34.7*	−48.3*	7.58*	3.14	4.15*	−0.97	0.29	1.38
ΔN	0.87	−1.62	−2.07	−5.47*	0.18	0.44	2.73*	1.84*	0.10	1.95
Δ (N/P)	1.13*	1.81*	2.02*	2.38*	−0.52*	−0.09	0.24*	0.43*	0.18	1.70

Notes: E is the change in total employment; P is the change in production workers; N is the change in nonproduction workers; and (N/P) is the change in the ratio of nonproduction workers to production workers. The changes are applied to detrended data for industrial production and the nonmanufacturing sectors. For the other three sectors, the changes are applied to the actual employment data. All data are from 1964 to 2000. Asterisks indicate significant coefficients at the 5% level based on Newey-West's heteroscadasticity and autocorrelation consistent covariances.

downward phases are between −126 and −412. For ΔP, the coefficients are between −120 and −380 whereas the coefficients are between −10.11 and −52.5 for ΔN. These magnitude differences are also found in upward phases and are present for all other four sectors as well.

There are two possible reasons that the coefficients for ΔE are closer to the coefficients for ΔP than to the coefficients for ΔN. First, on average, the number of production workers is 2 times (in the nonmanufacturing sector) to 2.8 times (in the nondurable goods sector) the number of nonproduction workers. With total employment dominated by production workers, it is reasonable to observe similar changes in total employment and in production workers. Second, if changes in the employment of nonproduction workers are relatively insensitive to business conditions, then the changes in total employment are mainly caused by the changes in production workers. This latter interpretation is consistent with the hypothesis that nonproduction labor has a quasi-fixed property.

To determine if the adjustments in the employment of nonproduction workers are relatively insensitive to business conditions, we examine the regressions for $\Delta\frac{N}{P}$. The coefficients for $\Delta\frac{N}{P}$ provide a formal comparison of the percentage change in production workers to the percentage change in nonproduction workers.[6] The positive and negative changes in employment and the N/P ratio from Table 2 are summarized in Table 3 with (+) meaning that a significantly positive change has occurred, (−) meaning that a significantly negative change has occurred, and (0) meaning that no significant change has occurred. Table 3 shows that negative signs for both ΔP and ΔN are found in seven stages of the downward phases. These seven stages are the last two stages of the downward phases for the industrial production, manufacturing, and durable goods sectors, and the last stage of the nondurable good sector. In these stages, the coefficients for $\Delta\frac{N}{P}$ are all positive and indicate the absolute value of the percentage changes in N are smaller than the absolute value of the percentage changes in P. This result is consistent with the quasi-fixed property of labor adjustment. It suggests that the adjustment of nonproduction workers is relatively small or is fixed compared to production workers. For upward phases, there are also seven stages with positive signs for both ΔP and ΔN. Among these seven stages, six of them have insignificant coefficients for $\Delta\frac{N}{P}$, and one has a positive coefficient for $\Delta\frac{N}{P}$. The insignificant coefficients in these six stages imply that the positive percentage change in N is the same as the positive percentage change in P. This may indicate a state of equilibrium. The only stage with a positive coefficient for $\Delta\frac{N}{P}$ is the third stage of the nondurable goods sector. This larger increase in nonproduction workers, than in production workers, may be caused by a lagged adjustment of nonproduction workers (see later discussion.). The relatively insensitive changes in the employment of nonproduction workers cannot be found in these seven stages of upward phases of business cycles.

The regressions for ΔP and ΔN, as well as the regression for $\Delta\frac{N}{P}$, compare the size of adjustments of production workers and nonproduction workers. In addition to this size comparison, a further examination of the quasi-fixed

[6] Note that $\Delta\frac{N}{P} = \frac{N}{P}\left(\frac{\Delta N}{N} - \frac{\Delta P}{P}\right)$. When $\Delta\frac{N}{P} > 0$, $\frac{\Delta N}{N} > \frac{\Delta P}{P}$. When $\Delta\frac{N}{P} < 0$, $\frac{\Delta N}{N} < \frac{\Delta P}{P}$.

Table 3. Signs of mean changes of employment in different stages of business cycles

	Downward phases				Upward phases			
	D1	D2	D3	D4	U1	U2	U3	U4
Industrial production								
ΔE	−	−	−	−	0	+	+	+
ΔP	−	−	−	−	0	+	+	0
ΔN	0[b]	0[b]	−[a]	−[a]	−[b]	0[b]	+	0
Δ (N/P)	0	+	+	+	−	−	0[d]	0[d]
Nonmanufacturing sector								
ΔE	−	−	−	−	0	+	+	+
ΔP	−	−	−	−	0	+	+	0
ΔN	0[b]	0[b]	0[b]	0[b]	−[b]	0[b]	+	0
Δ (N/P)	0	+	+	+	−	−	0[d]	0[d]
Manufacturing sector								
ΔE	−	−	−	−	+	+	+	0
ΔP	−	−	−	−	+	+	+	0
ΔN	0[b]	0[b]	−[a]	−[a]	0[b]	+	+	+[c]
Δ (N/P)	+	+	+	+	−	0[d]	0[d]	+
Durable goods production								
ΔE	−	−	−	−	+	+	+	0
ΔP	−	−	−	−	+	+	+	0
ΔN	0[b]	0[b]	−[a]	−[a]	0[b]	+	+	+[c]
Δ (N/P)	+	+	+	+	−	0[d]	0[d]	+
Nondurable goods production								
ΔE	−	−	−	−	+	0	+	0
ΔP	−	−	−	−	+	0	+	0
ΔN	0[b]	0[b]	0[b]	−[a]	0[b]	0[b]	+[c]	+[c]
Δ (N/P)	+	+	+	+	−	0	+	+

Notes: + Means a positive and significant coefficient, − Means a negative and significant coefficient, and 0 Means an insignificant coefficient.
[a] Indicates the relatively small adjustment of nonproduction workers.
[b] Lagged adjustment in nonproduction workers.
[c] Lagged adjustments with shift.
[d] Indicates short-run equilibrium.

property of nonproduction workers can be made by checking for lagged adjustments of nonproduction workers. This lagged adjustment of nonproduction workers could occur if the employment of nonproduction workers either: (a) stays the same in the early stages of downward phases and starts to decrease in the later stages of downward phases, (b) stays the same in the early stages of upward phases and starts to increase in the later stages of upward phases, or (c) increases in the early stages of downward phases or decreases in the early stages of upward phases.

Table 3 shows that ΔE for each sector are quite consistent with ΔP since ΔE and ΔP share the same pattern of negatives and positives, except for two stages (the last upward stage for the industrial production and nonmanufacturing sectors). Most importantly, the patterns of negatives and positives for ΔE and ΔP are consistent with downward and upward phases, i.e., most negatives are found in downward phases and positives are found in upward phases. However, the patterns of negatives and positives for ΔN, are very different from the patterns for ΔE and ΔP. These differences provide

important evidence concerning the lagged adjustment of nonproduction workers. This lagged adjustment can be summarized from Table 3 as follows.

(i) Industrial production sector: ΔN lags behind ΔP in D1, D2, U1, and U2.
(ii) Nonmanufacturing sector: ΔN lags behind ΔP in D1, D2, D3, D4, U1, and U2.
(iii) Manufacturing sector: ΔN lags behind ΔP in D1, D2, and U1.
(iv) Durable goods sector: ΔN lags behind ΔP in D1, D2, and U1.
(v) Nondurable goods sector: ΔN lags behind ΔP in D1, D2, D3, U1, and U2.

The above results show strong evidence that there is lagged adjustment of nonproduction workers in the early stages of downward and upward phases. Another check for the lagged adjustment of nonproduction workers using Table 3 is to compare the timing of the beginnings and endings of the changes in employment. For example, the positive changes in production workers for the manufacturing and durable goods sectors occur in U1, U2 and U3. For nonproduction workers, the positive changes occur in U2, U3, and U4. Changes in nonproduction workers lag behind changes in production workers by one stage in these two sectors. This lag shift of the positive changes is also found in the nondurable goods sector. In this sector, the positives occur in U1 and U3 for production workers, but occur in U3 and U4 for nonproduction workers. This lag shift phenomenon explains why the percentage changes in nonproduction workers are larger than the percentage changes in production workers in the last stage of the upward phases for these three sectors and in the third stage of the upward phases for the nondurable goods sector.

To summarize, a substantial amount of evidence for the quasi-fixed property of nonproduction workers with respect to production workers can be found in Tables 2 and 3. First, Table 2 shows the estimated coefficients for the changes in nonproduction workers are considerably smaller than those of production workers. This shows that the adjustment of production workers is relatively insensitive to changes in the business cycle. Second, relatively small percentage changes in nonproduction workers are found in several stages of business cycles. Third, Table 3 shows the estimated coefficients of the changes in nonproduction workers are insignificant in the early stages of downward and upward phases of the business cycle. This indicates lagged adjustments of nonproduction workers. Fourth, there are several sectors in which the entire adjustment phase for nonproduction workers is lagged and shifted. These results present strong evidence for the hypothesis that nonproduction workers represent a quasi-fixed part of the labor force.

2.3. Causal relationship between the changes in production and nonproduction workers

The above results indicate the dynamic adjustment of nonproduction workers often lags behind the dynamic adjustment of production workers. There are some pitfalls in using the above dummy variable regression, however. First, the construction of business cycles based on economic data is quite arbitrary since it is difficult to identify exact patterns of business cycles. Second, we assume shocks impact business cycles uniformly despite the differences in cycle length and location. For example, the above analysis assumes the

underlying properties of cycles occurring in the 1970's are similar to those occurring in the 1990's. The impact of technology and many other factors are held to be the same. Some of these assumptions may not be consistent with reality. This subsection uses an alternative approach to circumvent these problems. That is, we use the Granger causality test (Granger 1969) to check the timing differences of the adjustments.[7]

If production and nonproduction workers respond to shocks to the economy at the same time, the pace of the adjustment of both production and nonproduction workers should be the same. On the other hand, the quasi-fixed factor hypothesis suggests that the adjustment of nonproduction workers is slower than the adjustment of production workers. In this case, the adjustment of production workers comes first and is then followed by the adjustment of nonproduction workers. The change in the number of nonproduction workers is then a function of previous changes in production workers. This phenomenon can thus be described using the Granger causality model.

Denote the change in the number of production workers at time t as ΔP_t and the change in the number of nonproduction workers at time t as ΔN_t. Assuming the information set contains the previous changes, $\Delta P_{t-1}, \Delta P_{t-2}, \ldots, \Delta N_{t-1}, \Delta N_{t-2}, \ldots$, the Granger causality model is

$$\Delta P_t = a_0 + a_{11}\Delta P_{t-1} + a_{12}\Delta P_{t-2}, \ldots + a_{21}\Delta N_{t-1} + a_{22}\Delta N_{t-2}, \ldots + \varepsilon_{1t} \qquad (6)$$

$$\Delta N_t = b_0 + b_{11}\Delta P_{t-1} + b_{12}\Delta P_{t-2}, \ldots + b_{21}\Delta N_{t-1} + b_{22}\Delta N_{t-2}, \ldots + \varepsilon_{2t} \qquad (7)$$

When nonproduction workers lag behind production workers, the change in nonproduction workers at time t will coexist with the lags of the changes in production workers. The previous changes in production workers help to predict the changes in nonproduction workers. Therefore, ΔN_t is a function of the lags of ΔP_t, or ΔP causes ΔN in Eq. (7).

We estimate Eqs. (6) and (7) with the VAR model and apply a Wald test to check the causal relationship between ΔP and ΔN (Lütkepohl 1991). Table 4 shows the estimation of Eqs. (6) and (7) with the χ^2-statistics for the causality test in the last column.[8] The χ^2-statistics indicate that for three sectors, industrial production, nonmanufacturing, and nondurable goods, ΔP significantly causes ΔN, but ΔN does not significantly cause ΔP. This implies that lagged adjustments of nonproduction workers are found in these three sectors. For the other two sectors, the test results show a bi-directional causal relationship. When checking the impact of lagged ΔN on ΔP in Eq. (6), the estimated coefficients of the three lags of ΔN are 0.97, 0.23, and −0.85 for manufacturing sector, and the coefficients are 1.19, 0.55, and −0.97 for durable goods sector. Since the first lag has a positive and significant coefficient and the third lag has a negative and significant coefficient, an F test is applied to Eq. (6) to test the null hypothesis that the sum of three lagged coefficients of ΔN is zero. The F-statistic is 0.36 for manufacturing sector and

[7] An alternative method is to use the test of synchronization by Granger and Liu (1994).

[8] In estimating a VAR model, we use the Schwarz Information Criteria (SIC) (Schwarz 1978) to determine the number of lags to include in the model. Based on the SIC, three lags are selected for all sectors, except the nondurable goods sector. For the nondurable goods sector, SIC picks four lags. To simplify the table, only the results of the first three lags are presented in Table 4.

Table 4. Causality test for the changes in the production and nonproduction workers: Monthly data

		Lagged variables						χ^2
		ΔP_{t-1}	ΔP_{t-2}	ΔP_{t-3}	ΔN_{t-1}	ΔN_{t-2}	ΔN_{t-3}	
Industrial production	ΔP_t	0.21*	0.28*	0.25*	−0.11	−0.02	0.05	1.02
		(4.43)	(6.06)	(5.09)	(−0.94)	(−0.20)	(0.42)	a(0.80)
	ΔN_t	0.06*	0.05*	0.03	0.06	0.12*	0.03	45.28*
		(3.08)	(2.92)	(1.47)	(1.23)	(2.58)	(0.74)	(0.00)
Non-manufacturing	ΔP_t	0.03	0.30*	0.33*	−0.08	−0.03	0.11	2.25
		(0.70)	(6.93)	(7.14)	(−0.85)	(−0.38)	(1.26)	(0.52)
	ΔN_t	0.08*	0.07*	0.01	0.04	0.08	0.00	30.25*
		(3.27)	(3.04)	(0.58)	(0.77)	(1.65)	(0.05)	(0.00)
Manufacturing	ΔP_t	0.34*	0.15*	0.11*	0.97*	0.23	−0.85*	12.29*
		(7.02)	(2.91)	(2.13)	(2.93)	(0.73)	(−2.71)	(0.00)
	ΔN_t	0.03*	0.01	0.01	0.17*	0.24*	0.27*	49.64*
		(5.11)	(1.77)	(1.37)	(3.74)	(5.45)	(6.08)	(0.00)
Durable goods	ΔP_t	0.25*	0.08	0.15*	1.19*	0.55	−0.97*	20.40*
		(5.25)	(1.67)	(2.98)	(3.52)	(1.71)	(−3.01)	(0.00)
	ΔN_t	0.03*	0.02*	0.01	0.17*	0.26*	0.25*	37.44*
		(4.27)	(2.63)	(1.22)	(3.67)	(5.80)	(5.75)	(0.00)
Nondurable goods	ΔP_t	0.35*	0.29*	0.06	0.15	−0.19	−0.03	1.85
		(7.15)	(5.75)	(1.23)	(0.07)	(−0.91)	(−0.17)	(0.76)
	ΔN_t	0.03*	0.02*	0.02	−0.14*	0.12*	0.23*	42.71*
		(3.13)	(1.99)	(1.48)	(−2.97)	(2.65)	(5.59)	(0.00)

Notes: All data are from 1964 to 2000. The estimates of the constant are omitted from the table. The numbers in parentheses under the estimated coefficients are *t*-statistics. The numbers in parentheses under χ^2-statistics are *p*-values for the causality test. Asterisks indicate statistical significance at the 5% level.

is 0.77 for the durable goods sector showing that the total lagged impact of ΔN on ΔP is zero. This implies that the current change in production workers is related to lagged cyclical movements of the change in nonproduction workers. This cyclical movement of these series induces the bi-directional causal relationship between ΔN and ΔP, and therefore, the lag adjustment of nonproduction workers is undetermined in these two sectors. However, for all five sectors, there are no cases of one-directional causality where ΔN causes ΔP, such that production workers lag behind nonproduction workers.

When monthly data are applied to the dummy variable regressions, we found strong evidence of the lagged adjustment of nonproduction workers in all five sectors. The lack of evidence of lag adjustment in two sectors from the causality tests contradicts the results from dummy variable regressions. This contradiction may be caused by the cyclical movement in the time series. We solve this problem by using low frequency data. A time series is more likely to reveal cyclical movements in monthly data than in quarterly data. When examining lagged adjustments with quarterly data, the causality test will suffer fewer bi-directional causality problems from cyclical movements. Table 5 shows the causality tests with quarterly data. The causal relationships become clearer in Table 5 than in Table 4. All five sectors now show ΔN does not cause ΔP, but ΔP causes ΔN. Therefore, the adjustment of nonproduction workers lags behind the adjustment of production workers.

There are two potential problems in using quarterly data through temporal aggregation. First, if the number of periods of lagged adjustment is

Table 5. Causality test for the changes in the production and nonproduction workers quarterly data

	Dependent	Lagged variables		χ^2	
		ΔP_{t-1}	ΔN_{t-1}		
Industrial production	ΔP_t	0.75* (12.00)	−0.07 (−0.24)	0.11	(0.74)
	ΔN_t	0.13* (6.48)	0.29* (4.06)	42.02*	(0.00)
Nonmanufacturing	ΔP_t	0.76* (13.25)	0.03 (0.22)	0.05	(0.83)
	ΔN_t	0.15* (5.10)	0.21* (2.67)	26.04*	(0.00)
Manufacturing	ΔP_t	0.72* (9.05)	−0.58 (−1.46)	2.14	(0.14)
	ΔN_t	0.06* (6.19)	0.67* (13.62)	38.26*	(0.00)
Durable goods	ΔP_t	0.68* (8.35)	−0.25 (−0.66)	0.43	(0.51)
	ΔN_t	0.06* (5.59)	0.68* (13.81)	31.30*	(0.00)
Nondurable goods	ΔP_t	0.67* (8.71)	−0.80 (−1.87)	3.52	(0.06)
	ΔN_t	0.06* (5.79)	0.62* (11.53)	33.57*	(0.00)

Notes: All data are from 1964 to 2000. The estimates of the constant are omitted from the table. The numbers in parentheses under the estimated coefficients are t-statistics. The numbers in parentheses next to under χ^2-statistics are *p*-values for the causality test. Asterisks indicate statistical significance at the 5% level.

small, then lagged adjustments may not be observed after temporal aggregation. Second, Tiao and Wei (1976) and Wei (1982) show that a one-directional causal relationship may become a bi-directional causal relationship when temporal aggregated data are used. These two potential problems are not found in these data. If temporal aggregation does affect the conclusions about the causal relationship, the impact should be observed in both Eqs. (6) and (7). For the manufacturing and durable goods sectors, the temporal aggregation affects the causal relationship from ΔN on ΔP in (6), but does not affect the causal relationship from ΔP on ΔN in (7). This indicates that the temporal aggregation has removed the cyclical movements in monthly data. As a result, for quarterly data, the lagged adjustments of nonproduction workers become evident in all five sectors.

2.4. Long-run relationship between production workers and nonproduction workers

Although the results from the dummy variable regressions and the Granger causality tests provide evidence of the quasi-fixed property, it needs to be mentioned that these methods only apply to short-run analysis. In this subsection, we check the long-run equilibrium between production and nonproduction workers. When a demand or a supply shock occurs in the short-run, the adjustment of nonproduction workers may be relatively fixed. Eventually the adjustment of both nonproduction and production workers should respond to the long-run equilibrium output level. If this is the case, employment of both production and nonproduction workers converge to an "attractor" in the long-run. The econometric technique to test the existence of this "attractor" is cointegration (Granger 1986). Therefore, the hypothesis is that the employment of production workers and nonproduction workers should be cointegrated.

It is possible that this cointegration hypothesis is invalid. This would occur if forces drive the employment of either production workers or nonproduction workers away from the long-run equilibrium output path. Although there is no theoretical reason that this may occur, some studies show that the relationship between employment and output may change over time because of technology changes and international trade (Bartel and Sicherman 1998, and Berman, et al. 1994). The rejection of cointegration would then be an indication of an over-simplified long-run relationship between production and nonproduction workers.

To check the hypothesis that production workers and nonproduction workers move together in the long-run and are cointegrated, we use Johansen's cointegration test (Johansen 1991). Note that all the variables used in the dummy variable regressions and the causality tests are changes or first-order differences. The variables for the cointegration tests are in levels since they are being used for long-run analysis. Before any two series can be considered for the cointegration test, each series should be difference stationary. Table 1 shows that two of twenty employment series may not be difference stationary. Production workers for the manufacturing sector may be stationary, while production workers for the nonmanufacturing sector is integrated of order two. The conclusions concerning cointegration in these two sectors should be conservative. Table 6 shows the likelihood ratio tests for cointegration and the estimated coefficients for the regressions of the long-run relationships between production and nonproduction workers for the five sectors. The cointegration tests indicate the null hypothesis of zero cointegrating equations is rejected for each of the five sectors. Therefore, production and nonproduction workers are cointegrated and the two series are moving together in the long-run for each sector. This implies that both production and nonproduction workers converge to the long-run equilibrium determined by output. Other economic variables may have different short-run impacts on these employments, but over the long-run, these variables have no impact or have similar impacts on both production and nonproduction workers.

The coefficients in Table 6 show the number of nonproduction workers decreases as the number of production workers increases in the industrial

Table 6. Cointegration tests

Dependent	Independent variables			
Nonproduction workers	Constant	Trend	Production workers	LR test
Industrial production	9160	54.08	−0.036	30.45*
Nonmanufacturing	3983	50.95	−0.029	29.53*
Manufacturing	−1355	5.34	0.348	37.92*
Durable goods	−502	3.40	0.311	38.89*
Nondurable goods	−712	1.98	0.370	44.50*

Notes: The sample periods for industrial production and nonmanufacturing sectors are from 1964 to 2000 and are from 1947 to 2000 for the rest of the three sectors. The LR test is the Johansen's likelihood ratio test for cointegration when there is a constant and a trend in the cointegration equation. Asterisks indicate the null hypothesis of zero cointegrating equations is rejected at the 5% level.

production and nonmanufacturing sectors. This indicates that the two types of labor are slight substitutes in the long-run, after the trend patterns are considered. For the other three sectors, the estimated coefficients show the number of nonproduction workers increases as the number of production workers increases.

3. Conclusion

The quasi-fixed factor hypothesis of labor employment has been a part of the economics literature for a long time. As a result, many empirical researchers have tried to measure the dynamic adjustments of production workers and nonproduction workers. This paper, after recognizing the issues of nonstationarity for employment and output, uses three econometric techniques to examine the short and long-run dynamic adjustments of production and nonproduction workers and provides evidence for the short-run theory of labor being a quasi-fixed factor.

When monthly data of business cycles are divided into eight stages, we find using dummy variable regressions that total employment and the employment of production workers decrease during the downward phases of the business cycle and increase during the upward phases. This variability of labor employment is consistent with the economic theory of labor adjustment. We also find that the mean changes in nonproduction workers are considerably smaller than the mean changes in production workers in most stages of business cycles. In addition, by examining the changes in the ratio of nonproduction workers to production workers, we found several stages where the percentage change in nonproduction workers is relatively smaller than the percentage change in production workers. When checking the timing of the adjustment in employment in different stages of business cycle, the results indicate lagged adjustments of nonproduction workers. This evidence of different adjustment speeds is reenforced by the causality tests. The causality tests show that changes in production workers help to predict changes in the nonproduction workers. We conclude that the quasi-fixed property of labor employment occurs in the short-run.

In the long-run, the cointegration tests show both production workers and nonproduction workers are moving together along the economic equilibrium. The regressions for the long-run relationship show that the number of production workers and nonproduction workers are negatively related for the industrial production and nonmanufacturing sectors, and are positively related for the manufacturing, durable, and nondurable goods sectors in the long-run. Thus, the empirical results seem to show that the dynamic adjustment of production workers and nonproduction workers are connected in the long-run.

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