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THE CYCLICAL AND SECULAR BEHAVIOUR OF THE LABOUR INPUT: COMPARING EFFICIENCY UNITS AND HOURS WORKED

G. D. HANSEN

Department of Economics, University of California, Los Angeles, CA 90024, USA

SUMMARY

A monthly labour input series designed to correct for the fact that all hours worked are not of the same quality is constructed and its properties compared with unadjusted hours worked. This efficiency units series is constructed from BLS data on hours worked and earnings by age and sex. The cyclical fluctuations displayed by the efficiency units series are smaller on average than those displayed by hours worked, although the difference is not large. However, the secular behaviour of the series is quite different: hours worked *per capita* displays a significant positive trend while efficiency units *per capita* does not.

1. INTRODUCTION

Macroeconomists who use the neoclassical growth model to interpret the behaviour of observed aggregate time series typically employ some measure of total hours worked as the empirical counterpart to the labour input. For the post-war USA, the Bureau of Labor Statistics (BLS) publishes two independent hours series: one derived from the Current Population Survey (a survey of households) and the other based on establishment data. However, one source of measurement error that both of these series share is that they do not take into account the quality of the hours employed. The neoclassical production function treats all hours as identical, while in fact a young inexperienced worker will generally produce less in a given hour than someone who has been accumulating human capital over many years. If the relative fractions of high and low human capital workers employed changes over time, either secularly or over the business cycle, the measurement error involved may be quite large. This applies to productivity as well as to the labour input.[1]

In this paper we construct and study the properties of an 'efficiency units' time series designed to correct for this type of measurement error. In particular, we construct a labour input series where hours worked by different age–sex subgroups have been weighted by relative hourly earnings. Although we are not the first to suggest such a correction, the efficiency units series described here has the advantage that the data interval is sufficiently short (monthly) for

[1] That such a correction may have a significant effect on the cyclical behaviour of the labour input and productivity is demonstrated in a theoretical real business cycle context in Cho (1988) and Kydland (1984). In Cho's model, introducing heterogeneity in skill levels across individuals leads to fluctuations in total hours that are significantly larger than fluctuations in efficiency units. In addition, he finds that average productivity fluctuates more over the cycle if the labour input is measured in efficiency units.

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the series to be used in business cycle studies where a quarterly data interval is commonly employed.

More specifically, time series on total hours worked by age and sex published by the BLS and based on information from the household survey is used to construct a monthly efficiency units series for the period from July 1955 to June 1988. The method used to construct this efficiency units series is similar to that employed by Kydland and Prescott (1989). In their case, PSID data are used to construct an *annual* labour input series for 1969–82 by multiplying the hours worked by each individual by that person's average real compensation per hour over the same period.[2] The tradeoff here is that the PSID provides data on the hours worked and earnings of individuals, but only at an annual frequency. The BLS data used here are available monthly, but are provided for fourteen age–sex categories rather than for individuals.

In this note we first describe how the efficiency units series is constructed and then consider the properties displayed by this series compared with the unadjusted hours series. We focus on both the secular and cyclical properties of the time series. It turns out that the secular behaviour of efficiency units differs significantly from that of hours worked; hours worked *per capita* display a significant positive trend, while the efficiency units do not. This has the important implication that the efficiency units series, but not total hours, is, in principle, consistent with growth models that assume a unitary elasticity of substitution between consumption and leisure, as do standard real business cycle models of the type studied by Kydland and Prescott (1982).[3]

We also consider the cyclical properties of the two series. If during booms the marginal worker is less skilled than during recessions, the efficiency units series should display smaller fluctuations over the business cycle than the unadjusted hours series. We do in fact find that the efficiency units series displays smaller fluctuations on average than the hours series, although the difference between the two is not very large. In addition, we find that productivity measured in efficiency units is more highly contemporaneously correlated with GNP than productivity measured in physical units.

2. MEASURING EFFICIENCY UNITS

The efficiency units series is formed using monthly data from 7/55 to 6/88 on the number and average hours of persons at work in nonagricultural industries by age and sex. These series are derived from the Current Population Survey and published by the BLS, without seasonal adjustment, in *Employment and Earnings*. Total hours at work by age and sex are computed by multiplying these two sets of series together.

The number and definition of the age–sex subgroups for which data are available has changed several times over the sample period. For this reason, the sample period is divided into

[2] In addition, Jorgenson *et al.* (1987) use data from the Current Population Survey and the Census to construct an annual aggregate labour input series by weighting the hours worked by various subgroups of the labour force according to relative earnings. Darby (1984) also constructs an annual labour input series that corrects for changes in the demographic composition of the labour force, as well as other factors.

[3] This fact has lead others to use the efficiency units series described in this paper in studies based on real business cycle models as an alternative to the published hours series. See, for example, Burnside *et al.* (1990), Christiano (1988), Christiano and Eichenbaum (1990), and Prescott (1986).

Table I. Availability of data on average hours and number at work

	Dates (mth/yr)	Number of subgroups	Age subgroups	Source
1	7/55–12/58	14	14–17, 18–24, 25–34, 35–44, 45–54, 55–64, 65+	*Current Population Reports: Labor Force* (Bureau of Census) and unpublished data provided by BLS
2	1/59–3/63	12	14–17, 18–24, 25–34, 35–44, 45–64, 65+	*Employment and Earnings*
3	4/63–12/66	12	14–19, 20–24, 25–34, 35–44, 45–64, 65+	*Employment and Earnings*
4	1/67–6/76	10	16–19, 20–24, 25–44, 45–64, 65+	*Employment and Earnings*
5	7/76–6/88	14	16–19, 20–24, 25–34, 35–44, 45–54, 55–64, 65+	LABSTAT database (BLS)

five subperiods. Table I indicates the age–sex subgroups utilized in each subperiod and gives the source from which the data for that subperiod were obtained.[4,5]

Efficiency units are constructed by taking a weighted sum of the hours worked by each age–sex subgroup, where the weights reflect the relative productivity (human capital) of that subgroup. That is, if H_{it} is the total hours at work of subgroup i in period t, efficiency units in period t, E_t, is the following:

$$E_t = \sum_i \alpha_i H_{it} \tag{1}$$

where α_i is the weight, constant over time, associated with subgroup i. These weights are computed from data on average hourly earnings as follows:

$$\alpha_i = \frac{HE_i}{HE}$$

[4] The age–sex subgroups used in each subperiod were determined by two factors: first, the age brackets for which employment and average hours data are available and, second, the age brackets for which earnings data, used to form the weights, are available.

[5] The data from 5/70 to 5/76 on the number at work, which were obtained from monthly issues of *Employment and Earnings*, were revised to reflect information obtained from the 1980 census. This correction, which is described in the February 1982 issue of *Employment and Earnings*, has been applied by the BLS to all the data on labour force and employment levels maintained on its LABSTAT data tape. Unfortunately, the employment data used here are unavailable on LABSTAT before 6/76. Therefore, we make this correction ourselves so that the earlier data are consistent with the data obtained off LABSTAT.

One problem with the data that we were unable to correct for is that the hours worked by 14- and 15-year-old workers are included in the first three subperiods in Table I (data before 1967) but not in the later subperiods. This should not affect the properties of the resulting time series much since 14- and 15-year-old individuals account for a very small fraction of total hours worked. For example, a comparison of annual averages for 1966 and 1967 reveals that 14- and 15-year-old workers account for only 20 per cent of the hours worked by the 14- to 17-year age bracket and only 0·4 per cent of the hours worked by all age subgroups.

Table II. Weights assigned to age–sex subgroups

Males		Females	
Age	Weight	Age	Weight
16–19	0·56	16–19	0·52
20–24	0·78	20–24	0·69
25–34	1·14	25–34	0·89
35–44	1·37	35–44	0·90
45–54	1·39	45–54	0·87
55–64	1·33	55–64	0·84
65 +	0·89	65 +	0·66
14–17	0·56	14–17	0·52
14–19	0·56	14–19	0·52
18–24	0·78	18–24	0·69
25–44	1·24	25–44	0·89
45–64	1·37	45–64	0·86

In this expression, HE_i is average hourly earnings for subgroup i (where the averaging is over time and individuals in the subgroup) and HE is average hourly earning for all subgroups. These averages are computed using annual data from 1979 to 1987. In Appendix 1 we describe the method and data used to compute hourly earnings for each subgroup. The actual weights used (the α's) are listed in Table II. In addition, quarterly averages of the efficiency units series (E_t from 55:3 to 88:2 with no seasonal adjustment) are provided in Appendix 2.

3. COMPARING EFFICIENCY UNITS AND HOURS WORKED

In Figure 1 quarterly data on hours worked divided by population are plotted using two commonly used hours series, one based on household survey data and the other based on establishment data.[6] In addition, a linear trend has been fitted to these series. Both of these series display significant trends. Now consider Figure 2, where seasonally adjusted quarterly averages of *per capita* efficiency units and total hours at work are plotted. The latter is formed by simply summing the hours worked by each age–sex subgroup (setting $\alpha_i = 1$ for all i in equation (1)). The seasonal adjustment was done by computing a linear regression on quarterly seasonal dummies. As in Figure 1, we also show the linear trend associated with each of these series. The two series in Figure 2 display a very significant difference in trend—the hours worked series shows a significant upward trend, while the efficiency units series shows only a very slight downward trend, which is statistically insignificant.[7]

To illustrate this property in a different way, Figure 3 shows the ratio of efficiency units to hours at work. This illustrates a reduction in the quality (as measured by relative earnings) of

[6] The household series is total hours at work per week in nonagricultural industries (billions of hours, seasonally adjusted). The unadjusted data are available from the Bureau of Labor Statistics' LABSTAT database. Seasonal adjustment was done by regressing on quarterly seasonal dummies. The establishment series is employee hours in nonagricultural establishments. The seasonally adjusted data was obtained from Citibase (LPMHU). *Per capita* series were formed by dividing by total population of individuals 16 years and over. The data shown run from 55:3 to 88:2.
[7] The significant positive trend in hours worked continues to be present if some of the more recent observations are eliminated. It is present, for example, if only data through 1982 are used. However, for this shorter period, the downward trend in the efficiency units series is more significant.

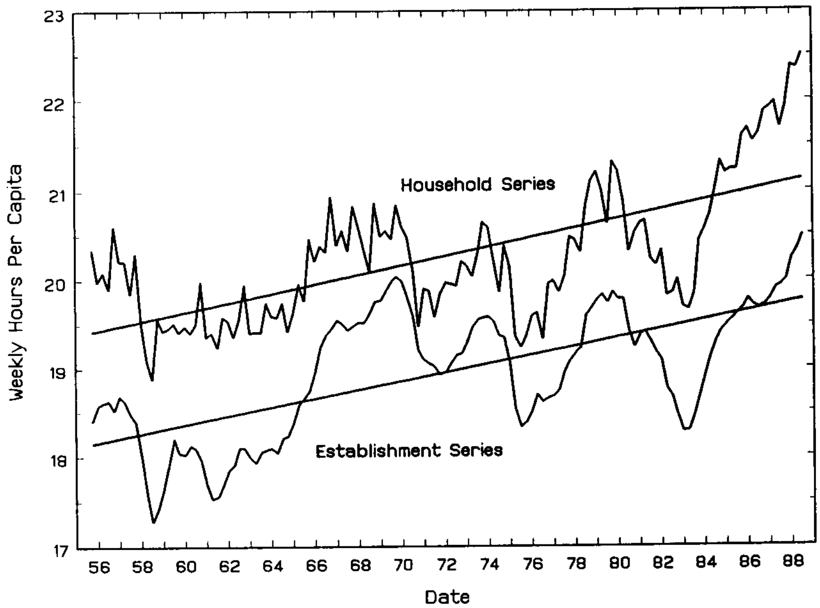

Figure 1. Weekly hours at work

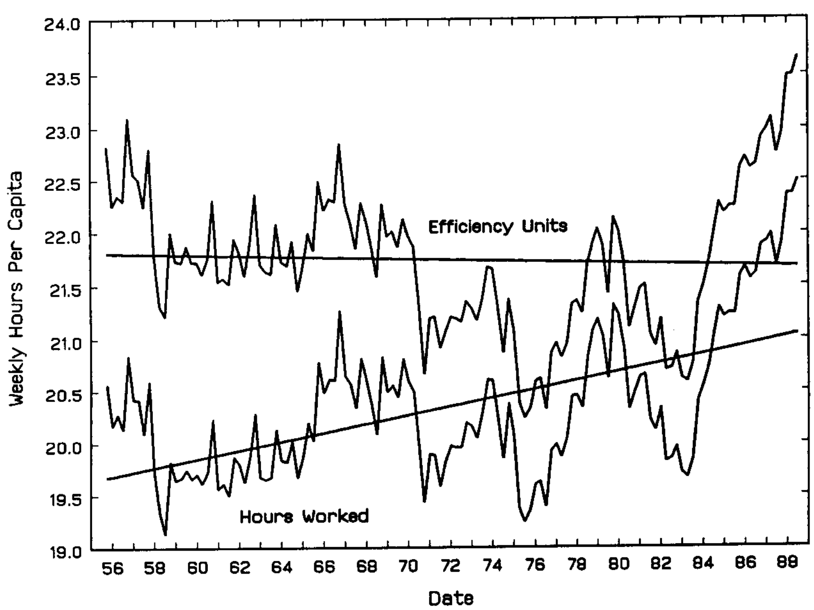

Figure 2. The labour input before and after efficiency units correction

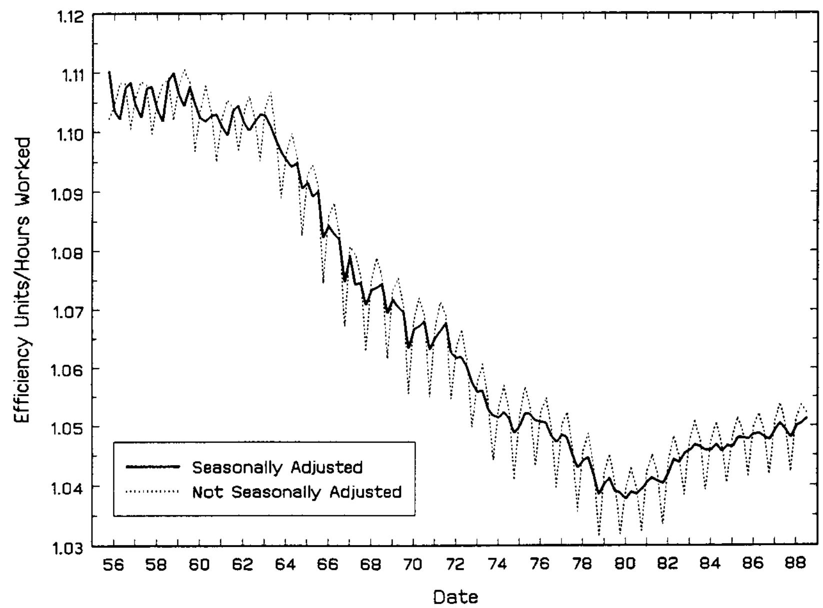

Figure 3. Ratio of efficiency units to hours worked

the employed work force that occurred from the early 1960s to the end of the 1970s. The nonseasonally adjusted version of this ratio is also plotted to illustrate the extreme seasonality of this ratio. There are sharp downward spikes during the third quarter of each year, presumably reflecting a larger share of young, relatively low-wage, workers during the summer.

To compute summary statistics for comparing the cyclical properties of these two series, we logged and detrended the data using the Hodrick-Prescott (1980) filter, a procedure common in applied work based on equilibrium business cycle models. These summary statistics are given in Table III. The data used to compute the summary statistics are the same seasonally adjusted quarterly averages shown in Figure 2. In addition, data on real GNP over the same sample period have been used to compute average productivity series with respect to these two labour-input series.

Table III reveals that the cyclical properties of the efficiency units series are quite similar to the properties of the total hours series. Efficiency units display somewhat smaller fluctuations

Table III. Cyclical behaviour of labour input (deviations from trend—seasonally adjusted quarterly data, 1955,3 1988,2)

Variable x	Volatility (% std dev.)	Cross-correlation of real GNP with						
		$x(t-3)$	$x(t-2)$	$x(t-1)$	$x(t)$	$x(t+1)$	$x(t+2)$	$x(t+3)$
Real GNP	1·73	0·37	0·63	0·85	1·00	0·85	0·63	0·37
Total Hours	1·75	0·27	0·46	0·63	0·76	0·72	0·63	0·46
Efficiency Units	1·66	0·27	0·46	0·63	0·74	0·70	0·60	0·43
GNP/Hours	1·21	0·15	0·24	0·31	0·34	0·17	−0·01	−0·13
GNP/Eff. Units	1·22	0·16	0·27	0·35	0·41	0·26	0·08	−0·05

on average, a result that one would expect if lower productivity workers represent a larger fraction of the employed work force during booms than they do in recessions. Similarly, productivity measured in efficiency units display somewhat smaller fluctuations, on average, than the productivity measured in physical units. These results are qualitatively (though not quantitatively) consistent with the theoretical findings of Cho (1988). We also find that productivity defined in terms of efficiency units is more procyclical (the contemporaneous correlation with output is larger) than productivity defined in terms of actual hours worked. These results are not sensitive to small changes in the weights used to construct the efficiency units series (see Appendix 1).

These findings are in marked contrast to those of Kydland and Prescott (1989). They find that the cyclical properties of their efficiency units series computed from PSID panel data are quantitatively quite different from the properties of their corresponding aggregate hours series. For example, they report a percentage standard deviation of hours worked equal to 1·5 and a percentage standard deviation of 0·98 for efficiency units. Presumably, their results differ from the ones reported here because they use data on individuals to construct an efficiency units series rather than data on relatively broad age–sex subgroups. In particular, there appear to be large differences in the cyclical properties of the hours worked by differently skilled individuals within the age–sex categories used here, prime age males in particular. This indicates that it would be desirable to construct a monthly (or quarterly) efficiency units series from more disaggregate data by using information directly from the Current Population Survey rather than data published by the BLS. Although this would likely be a very difficult and time-consuming project, such a labour-input series would combine the advantages of Kydland and Prescott's (1989) approach with the advantages of the approach used here.

APPENDIX 1: PROCEDURE FOR COMPUTING WEIGHTS

The weights used in constructing the effective units time series are based on the following series:[8]

WEPT Median weekly earnings for employed part-time wage and salary workers (usually work $\leqslant 34$ hours per week).

WEFT Median weekly earnings for employed full-time wage and salary workers (usually work $\geqslant 35$ hours per week).

NPT Number of wage and salary workers who work part-time.

NFT Number of wage and salary workers who work full-time.

AVHR Average hours for wage and salary workers at work in nonagricultural industries.

The earnings data are published for fourteen age–sex subgroups, the same subgroups as in subperiod five of Table I. From these data an annual measure of hourly earnings for each subgroup (HE_{it}) was constructed by dividing total earnings by total hours worked:

$$HE_{it} = (WEPT_{it}NPT_{it} + WEFT_{it}NFT_{it})/AVHR_{it}(NPT_{it} + NFT_{it})$$

for $i = 1–14$ and $t = 1979–87$.

[8] All of these series are annual data from 1979 to 1987 (1979 is the first year for which these earnings data are available). The number of full-time and part-time wage and salary workers and their median weekly earnings were obtained from unpublished tabulations supplied by the BLS. The data on average hours of wage and salary workers (AVHR) were taken from the LABSTAT data tape.

In some of the earlier subperiods, hours data are provided for age–sex subgroups that do not correspond to one of the fourteen age–sex subgroups for which earnings data are available (see Table I). To compute hourly earnings for the age brackets that are simply combinations of two of the original age groups, it is possible to simply sum total earnings over the component subgroups and divide by combined total hours. This procedure is used for the 25–44 and 45–64 age brackets appearing in Table I. The 14–17 and 18–24 age groups appearing in subperiods 1 and 2 and the 14–19 age group appearing in subperiod 3 are not combinations of the age groups for which earnings data are available. Our solution is to approximate the hourly earnings for the 14–17 and 14–19 age groups with the hourly earnings for the 16–19 age groups. Similarly, the earnings of the 18–24 age groups are equated with the earnings of the 20–24 age groups.[9]

The next step is to compute average hourly earnings for each age–sex subgroup (HE_i) by averaging HE_{it} it over the nine-year sample. The weights are formed by normalizing HE_i with respect to the average hourly earnings over all subgroups. That is,

$$\alpha_i = HE_i/HE,$$

for all age–sex subgroups i, where

$$HE = \frac{\Sigma(NFT_i + NPT_i)HE_i}{\Sigma(NFT_i + NPT_i)}$$

where NFT_i and NPT_i are averages over $t(t = 1979\text{–}1987)$. These weights, α_i, for all age–sex subgroups i, are listed in Table II.

Although the weights we use are constructed from mean hourly earnings over the 1979–87 sample period, one may be interested in how relative earnings have changed over this sample period. In general, the weights computed separately for each year display slight, monotonic trends. In Table IV, the weights computed for 1979 and 1987 for each of the 14 age–sex subgroups are listed. To explore the sensitivity of our results to small changes in the weights, the statistics in Table III have been recomputed using these alternative sets of weights. The statistics were affected very little, demonstrating that the findings are robust to reasonable changes in the weights used.[10]

Table IV. Weights computed for individual years

Age	Males		Females	
	1979	1987	1979	1987
16–19	0·63	0·52	0·57	0·48
20–24	0·87	0·74	0·71	0·68
25–34	1·20	1·09	0·88	0·89
35–44	1·34	1·35	0·85	0·94
45–54	1·37	1·39	0·83	0·92
55–64	1·28	1·35	0·82	0·87
65 +	0·84	0·93	0·65	0·68

[9] The fact that we must approximate hourly earnings in this way is not too bothersome, given that the properties of the effective units time series are not sensitive to small changes in the weights.

[10] The statistics for average productivity (GNP/Eff. Units) were more sensitive to the weights used than were statistics for the efficiency units series. Still, the differences were small. Depending on the weights used, the percentage standard deviation of this series ranged from 1·20 to 1·23 and its contemporaneous correlation with GNP ranged from 0·40 to 0·42.

APPENDIX 2: QUARTERLY EFFICIENCY UNITS

Not seasonally adjusted
Computed from billions of hours at work

Year	*Quarter 1*	*Quarter 2*	*Quarter 3*	*Quarter 4*
1955	NA	NA	2·3975	2·5102
1956	2·4764	2·5167	2·4559	2·5716
1957	2·5211	2·5391	2·4532	2·5163
1958	2·4200	2·4542	2·3942	2·5416
1959	2·4983	2·5650	2·3988	2·5759
1960	2·5289	2·5922	2·5089	2·5956
1961	2·5578	2·5983	2·5008	2·6582
1962	2·5847	2·6706	2·5814	2·6849
1963	2·6387	2·6860	2·5978	2·7344
1964	2·6900	2·7688	2·5651	2·7755
1965	2·7747	2·8041	2·7394	2·8828
1966	2·8531	2·8965	2·8203	2·9233
1967	2·8587	2·8764	2·7903	2·9492
1968	2·8780	2·8888	2·8349	2·9763
1969	2·9445	2·9762	2·8680	3·0296
1970	2·9799	2·9642	2·7291	2·9876
1971	2·9554	2·9702	2·8502	3·0564
1972	3·0371	3·0877	2·9748	3·1486
1973	3·0975	3·1800	3·0843	3·2680
1974	3·1786	3·1710	3·1048	3·2450
1975	3·1040	3·1366	3·0115	3·2355
1976	3·2041	3·2116	3·1544	3·3534
1977	3·2948	3·3703	3·2875	3·4774
1978	3·4228	3·5506	3·4398	3·6504
1979	3·5897	3·5686	3·5469	3·7137
1980	3·6283	3·5788	3·4688	3·6789
1981	3·6471	3·6199	3·4554	3·6804
1982	3·5566	3·6090	3·4889	3·6253
1983	3·5787	3·6589	3·6116	3·8187
1984	3·8196	3·9175	3·8241	3·9875
1985	3·9566	4·0046	3·9242	4·1242
1986	4·0717	4·1287	4·0316	4·2260
1987	4·2101	4·2008	4·0895	4·3654
1988	4·3276	4·4066	NA	NA

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