Carnegie-Rochester Conference Series on Public Policy 21 (1984) 173-208
North-Holland

LABOR-FORCE HETEROGENEITY AND THE BUSINESS CYCLE

Finn E. Kydland*
Carnegie-Mellon University

I. INTRODUCTION

In the past ten or so years, there has been a revival of interest in equilibrium models of the business cycle. The view had been that accounting for the persistence of cyclical movements in output and other important aggregates would be an extremely challenging, if not impossible, task with such models. The important paper by Lucas (1972) led to models which are consistent with monetary shocks resulting in persistent equilibrium movements of real aggregates.[1] The key to these results was the richness of the information structure, and it was only natural that less effort went into developing the details of propagation mechanisms that might be present on the real side of the economy. Although there was an underlying notion that the economy is inhabited by optimizing agents who process information efficiently within the specified information sets, it was not always necessary to work out the optimization part explicitly in order to bring home the point of this research. Instead, simple formulations emphasizing intertemporal substitution effects and intended to mimic such dynamic behavior were often used.

Several factors may have contributed to a recent trend in the direction of analyzing models of the aggregate economy in which decisions are derived from explicitly formulated optimization problems. First, there was the realization that the parameters of these optimization problems are part of what we will ultimately want to estimate in order to evaluate systematic

*This research was started while I was visiting the Hoover Institution. I am grateful to the National Science Foundation for financial support and to James Heckman, Joseph Hotz, Edward Prescott, Guilherme Sedlacek, and Kathryn Shaw for helpful discussions.

[1]See Lucas (1975), Barro (1976), and subsequent work.

tax changes and other government policies with confidence.[2] Some people realized that, in addition to monetary shocks, technological and other real shocks may also be important factors in the business cycle. In order to analyze the effects of such shocks, the real propagation mechanisms deriving from preferences and technology became essential.[3] It is clear, however, that the importance of such mechanisms does not depend on the nature of the shocks. Their formal inclusion in monetary theories would presumably also make these theories more powerful in explaining the observations.

Most importantly, the attractiveness of optimizing, competitive-equilibrium theories largely stems from the discipline they impose on the researcher wishing to understand the nature of business cycles.[4] Such models allow for considerable richness in dynamic aggregate behavior while keeping the number of free parameters small.[5] Recent methodological advances have made their analysis feasible. Such models have to abstract from many things in order to serve their purpose and can obviously not yet be expected to fit the data well according to usual goodness-of-fit criteria. Adding parameters that might be motivated, for example, by disequilibrium phenomena would improve the fit, and a basis in realism could probably be given. As with most scientific effort, however, it is generally the case that insisting on too much realism reduces the chances of learning anything useful.

If one accepts this basic approach, it is obviously still the case that a great variety of models would fit that general description. That is, we have to find out which are the right model elements to put into such a theory. Given the novelty of this line of research, however, it is only natural that we have not gotten very far in determining what they are. The

---

[2] For a recent statement on the need for this approach, see Sargent (1982). See also Lucas (1976).

[3] Examples of formal models emphasizing such elements are in Kydland and Prescott (1980, 1982), Long and Plosser (1983), Becketti (1983), and Altug (1983).

[4] See Lucas (1980) for a thorough discussion.

[5] I am here referring to the infinitely-lived-agent framework, which appears particularly convenient for being confronted with data, including the imposition of a priori restrictions. An alternative dynamic optimizing framework, of course, is the overlapping-generations model, which may be more appropriate for theoretical analysis when one is not yet serious about the data. See McCallum (1982) for an evaluation of its usefulness.

main purpose of this paper is to discuss several model features as they relate to employment variation over the cycle.

Much of dynamic equilibrium analysis, both theoretical and empirical, in the past ten years has been conducted within a framework where the objective function of a representative or stand-in agent is being maximized. The possibility of finding equilibria in this way follows from a well-known connection, under some conditions, between competitive equilibria and Pareto optima.[6] This approach is particularly appealing when agents are homogeneous, since then there is a unique Pareto optimum.[7] The application of this idea to dynamic models was inspired in particular by the elegant paper by Lucas and Prescott (1971) in which they show how to determine industry equilibria by solving a particular stand-in problem. Much recent econometric work in which explicit maximization problems are written down relies heavily on that framework.[8]

It is probably fair to say that the representative-agent abstraction is viewed with suspicion by many labor economists. After all, heterogeneity has been an essential element of much of their work, and they generally find it necessary to include both observed and unobserved heterogeneity in their models in order to explain the observations. Skill as well as taste differences have played a big role.

This observation might appear to present the macroeconomist with a problem if he wants to use an optimizing framework but at the same time would like to have his models be consistent with micro observations. The representative-agent framework is methodologically convenient and makes dynamic analysis tractable in a disciplined way. Labor markets are clearly central, however, to understanding business cycles. One of the key features of cycles is that hours of work show substantial variability, while the real wage or the average product of labor fluctuates relatively little. A successful theory should be consistent with these observations. One is potentially faced with a difficult problem, however, if one is to take heterogeneity as seriously as most labor economists do.

In this paper, I shall discuss the need for integration of labor-force heterogeneity into business-cycle theory. Allowing for differences in

---

[6]See Debreu (1954).

[7]See Prescott and Mehra (1980).

[8]See for instance Sargent (1981) and Hansen and Singleton (1983).

skills appears particularly promising. It is well-kown that the hours of less-skilled groups, such as youth, fluctuate relatively much more than, say, those of prime-age males over the cycle. Yet, the *quantitative* importance of this effect is not well-established. In the next section, I present both old and new evidence, the latter based on the Panel Study on Income Dynamics. Then I analyze a model of the aggregate economy in which there are two types of skills. The model represents an extension of the one in Kydland and Prescott (1982) which contains an explicit specification of preferences, technology, and information structure within a dynamic general-equilibrium framework. In addition to the observation that relative hours' variability is different across skill groups, a version of the present model is also motivated by the observation that wage differences narrow in booms and widen in recessions.

An element needed in that model in order to be consistent with aggregate observations is a non-time-separable utility function which admits greater intertemporal substitution of leisure.[9] This is contrary, however, to what labor economists have found, using panel data. Towards the end of the paper, I discuss possible explanations, and also implications for aggregate modeling, of this apparent conflict between individual and aggregate evidence.

II. EMPLOYMENT VARIATION AMONG SKILL GROUPS

It is a well-known stylized fact that unskilled workers in the United States labor force exhibit greater employment fluctuation over the business cycle than do skilled workers. Yet, I have found few attempts in the literature at quantifying this effect. One problem, of course, is that it is not obvious how to measure skills. Some candidates as indicators of skills within broad occupational groups might be age, education, average

---

[9]The potential importance of intertemporal substitution of leisure was suggested empirically by the work of Lucas and Rapping (1969). They found that the short-run labor-supply elasticity is high, while long-run supply is inelastic. This feature has been an important basis for many models in modern aggregate-equilibrium theory. Brunner, Cukierman, and Meltzer (1980, 1983), for instance, have formulated detailed models in which they have labor-supply functions with similar properties to the one estimated by Lucas and Rapping (1969). They also assume, again in the spirit of Lucas and Rapping, that shocks have unobservable permanent and transitory components, and show that many qualitative features of the business cycle are consistent with that theory. See also Hall (1980).

hourly wage, experience, or tenure. Either of these alone would not necessarily be a good measure. Where such measures may have been available, the data perhaps did not cover enough years to yield any clear business-cycle effects.

Two basic approaches have been used. One is to divide the population into demographic groups in such a way that one could agree that some groups on the average represent higher skills than others. This has been done by Mincer (1966) and Clark and Summers (1981). The division is in terms of males and females of different age groups. Clark and Summers say on p. 70:

> A key result of the calculations is that young workers account for the larger part of the cyclical variations in employment. While teenagers comprise less than a tenth of the population, they account for more than a fourth of cyclical fluctuations. Teenagers and young women 20-34 represent only 25 percent of the adult population, yet they experience close to 50 percent of the cyclical variation in employment. Prime age males 25-64 are a large fraction of the population (32.6 percent), but account for less cyclical employment variation than teenagers who represent only 9 percent of the population.

Rosen (1968), on the other hand, studies a particular industry, namely the railroad industry, and divides the employees into occupational groups that can be ranked according to skills. He also finds that employment varies more for the unskilled workers.

The purpose of this section is to study the groups of prime-age males for whom Clark and Summers and Mincer find relatively little variation to see if other indicators of skills, such as education, suggest substantially different variability within those groups. For that purpose, I shall use the Panel Survey of Income Dynamics for the 11-year period 1970-80.[10] In addition to education, one could also consider experience. This variable, however, is defined as age minus years of education minus six and is unlikely to be helpful if education and age are both already accounted for.

Of particular interest is the subsample of males who were more than 40 years of age in 1980. In order to obtain broad characteristics of this

---

[10] I am grateful to Kathy Shaw for giving me access to her data sets.

sample along the dimensions of interest, I divided it into five fairly evenly-numbered groups by years of education and measured average hours worked per year, average standard deviation of hours (that is, the standard deviation for the up-to-eleven observations per individual was computed and then averaged within each group), and average hourly real wage rate. I included only individuals for whom there were at least three observations of nonzero hours, and I excluded a couple of obvious cases of measurement error in which a number of hours greater than 16x365 were reported. Finally, I used an upper-age limit of 70.

For other purposes, it is clear that one may want to use stricter criteria for inclusion in the sample. It is well known that measurement errors are likely to be substantial in the PSID. For example, each individual was asked to report total labor income and hours worked in the previous year, and then hourly wage was determined by simply dividing the two numbers. To the extent that some people may report an hours' figure that is grossly inaccurate, it is clear that the wage rate will then be off in the opposite direction. Thus, when there is an increase, for instance, in the real wage rate by a factor of five or ten from the previous year, with a corresponding decrease in hours worked that year, it seems that one has a good case for excluding those observations as extreme cases of measurement errors. In what is reported below, however, I have not thrown out any of those observations.

The results are presented in Table 1. Since the reported number of years of education for a few individuals changes over the sample period, I used the average as a criterion for dividing the sample into the five skill groups. We see that the average standard deviation of annual hours rises substantially in going from the highly educated to the less educated, while the average number of hours worked declines. Thus, average relative variability in the bottom group (32.4 percent) is about twice as high as that of the top group (16.3 percent). We also see substantial average real-wage differences, with the first group earning an average hourly wage of about 2.5 times that of the last group.

These statistics are suggestive but do not really tie the variation in with aggregate economic activity. As a further attempt to get a quantitative feel for the magnitudes of the effects in these groups, I used the overall unemployment rate for males over 20 as the indicator of the business cycle. Letting u_t be the unemployment rate in year t and d_i a dummy variable which is one if the individual is in education group i, i = 1,...,5, and zero otherwise, the regression estimates were

$$h_t = \underset{(100.3)}{2494.0} - \underset{(126.2)}{116.8d_{1t}} - \underset{(128.7)}{1.1d_{2t}} - \underset{(119.2)}{56.1d_{3t}} - \underset{(126.4)}{47.0d_{4t}} - \underset{(2.8)}{43.8t}$$

$$+ \underset{(16.4)}{30.6d_{1t}u_t} - \underset{(18.3)}{10.8d_{2t}u_t} - \underset{(13.5)}{15.2d_{3t}u_t} - \underset{(15.9)}{41.6d_{4t}u_t} - \underset{(22.6)}{91.0d_{5t}u_t},$$

with standard errors in parentheses. The sample included 10,985 observations, and the R^2 was 0.06. Group-specific constant terms were included to account for the differences in average annual hours across the groups. The coefficients for $d_{it}u_t$ indicate that an increase in the aggregate unemployment rate by one percentage point widens the difference in hours worked per year for the two most extreme groups by more than one hundred. Omitting the time trend made little difference in the relative magnitudes of these coefficients.

TABLE 1

Years of Education	Means of Annual Hours	Average Standard Deviations of Hours	Average Real Wage	Number of Individuals
E>15.9	2253.1	366.6	6.79	188
12.1<E≤15.9	2168.8	464.0	4.77	282
11.9<E≤12.1	2129.8	437.8	3.91	190
7.9<E≤11.9	1989.4	531.4	3.52	213
E≤ 7.9	1801.9	584.0	2.74	141
				1014

It is possible that these differences in employment variation over the business cycle could be somewhat overstated because the oldest people in the sample reduce their working hours and represent a relatively higher proportion of the groups with less schooling. I also looked at a younger sample for whom this should not be a problem. It contained 723 males who were between the ages of 31 and 40 in the last year of the sample period. Since the below-twelve-year education group was much smaller, I merged the lowest two groups. With this modification, but in an otherwise similar regression equation, the coefficients for d_1u_t through d_4u_t were 16.1, -9.4, -34.4, and -68.2.

These estimates based on the PSID, along with previous findings referred to above, all suggest that differences in employment fluctuation among various skill groups are quantitatively important. If we constructed a measure $\sum_i \pi_i w_i \bar{h}_{it}$ over time of average hours measured in efficiency units, where π_i is the fraction of people in skill group i, w_i is the average real wage in group i and represents the relative efficiency of this group, and we compared this measure with the unweighted measure $\sum_i \pi_i \bar{h}_{it} = \bar{h}_t$ used in aggregate data, then the former should fluctuate considerably less than the latter, especially if females and teenagers were included as well. The first measure could be viewed as the empirical counterpart of the hours variable in the Kydland-Prescott model. Based on the above findings, one would expect the variability to be substantially less than the variability of the unweighted measure used in aggregate data.

III. SKILL DIFFERENCES IN AN AGGREGATE EQUILIBRIUM MODEL

This evidence that employment behavior differs widely over the cycle depending on skill groups would seem to question the usefulness of representative-agent models for aggregate equilibrium analysis. They go back to the optimal-growth model of Cass (1965) and Koopmans (1965), which has been extended to stochastic environments by Brock and Mirman (1972) and pushed further by Danthine and Donaldson (1981). These models, however, have no role for employment fluctuation, which is a key characteristic of the business cycle in contrast with longer-run movements.[11]

The paper by Kydland and Prescott (1982) represents a generalization of the stochastic growth model and also deals with cyclical phenomena. Like the growth model, its main source of randomness is technology

[11] There is a sense in which one can formally allow for heterogeneity in these models as long as it enters in such a way that one can aggregate. In other words, for some models the equilibrium can be found by simply solving the optimization problem of the average agent. Examples are in Kydland (1983a). Such a model could not capture the essential features of skill differences.

shocks. Also, the model assumes an investment technology in which it takes time to build new productive capital and assumes that utility is intertemporally nonseparable in leisure. The model was partly motivated by trying to explain the large cyclical-employment variation associated with relatively little real-wage or productivity fluctuation in the postwar United States economy. The intention was to see how well the simple dynamic abstraction could explain some of the key variance-covariance properties of postwar data. Another purpose was to contrast these model elements with prominent alternatives, such as a standard time-separable utility function and a cost-of-adjustment investment technology.

The model was first calibrated to be consistent with average relations in the data for which the signal-noise ratio is high and with well-established facts from microdata. This left only a handful of parameters to be varied. The statistics used for comparing the model with aggregate data were autocorrelations of cyclical output of order up to six, the relative standard deviations of the cyclical components of all the variables, and their correlations with cyclical output. The test of the theory was whether the magnitudes of those statistics from the model were not only qualitatively but also quantitatively similar to the corresponding statistics in the data. That is, the model had to be consistent along each of nearly twenty dimensions, where closeness was defined in terms of standard deviations of each of the statistics under repeated sampling from the model with the same sample length as in the United States data.

The described test is obviously a tough one to pass, and it was clearly too much to expect that such a simple theory would be consistent along all dimensions. It is interesting to note that the only major discrepancies were related to employment behavior. While the model performed substantially better with an intertemporally nonseparable utility function than with the standard separable one, cyclical employment variation remained about one-third too small, and there was the related problem that the average product of labor was too highly correlated with output.

This phenomenon can reasonably be viewed as a measurement problem relative to the abstraction used. One must interpret hours in the model as being measured in efficiency units. As is suggested in the previous section, it is not unreasonable to think that the discrepancy in fluctuations between efficiency units and unweighted hours is of that magnitude. On the other hand, it is probably harder to argue that hours measured in efficiency units is the appropriate argument of the utility function for the less skilled. In the remainder of this section I shall describe a version of the model in Kydland and Prescott (1982) which allows for heterogeneity of skills in the production function, with preferences being functions of actual hours of leisure. The description of the parts of the model that are unchanged will be brief, and I refer to that paper for much of the motivation for those elements.

Total output, consisting of consumption c_{1t} and c_{2t} by the two types of individuals and investment x_t, is constrained by

$$c_{1t} + c_{2t} + x_t = f(\lambda_t, k_t, n_{et}, y_t), \tag{3.1}$$

where λ_t is a technological shock, k_t and y_t are the stocks of productive physical capital and inventories, respectively, at the beginning of period t, and n_{et} is labor input measured in the efficiency units of unskilled labor, that is, $n_{et} = \omega n_{1t} + n_{2t}$, where ω is greater than one. The production function is

$$f(\lambda_t, k_t, n_{et}, y_t) = \lambda_t n_{et}^{\theta}[(1-\sigma)k_t^{-\nu} + \sigma y_t^{-\nu}]^{-(1-\theta)/\nu}$$

where $0 < \theta < 1$, $0 < \sigma < 1$, and $0 < \nu < \infty$. The parameter θ is determined by the average labor share, while the average capital-inventory ratio restricts either σ or ν.

The technology assumes that time is required to build productive capital. If J periods are required, then the laws of motion for finished and unfinished capital stocks are

$$k_{t+1} = (1-\delta)k_t + s_{1t}, \tag{3.2}$$

$$s_{j,t+1} = s_{j+1,t}, \quad j = 1,\dots,J-1, \tag{3.3}$$

where s_{jt} are projects j periods from completion, and δ is the depreciation rate. Thus, s_{Jt} is a decision variable in period t and represents planned additions to the capital stock that will become productive in period t+J. Let ϕ_j, $j = 1,\dots,J$, be the fraction of the resources allocated to projects in the jth stage from the last. Then total investment in period t is the sum of investment in capital and inventory investment:

$$x_t = \sum_{j=1}^{J} \phi_j s_{jt} + y_{t+1} - y_t. \tag{3.4}$$

The two types of individuals are assumed to maximize the expected values of utility functions $\Sigma_{t=0}^{\infty}\beta^t \; u_i(c_{it},\alpha_i(L)\ell_{it})$, $i = 1,2$, where $0 < \beta < 1$ is the discount factor, ℓ_{it} is leisure consumed by the ith type in period t, L is the lag operator, and $\alpha_i(L) = \Sigma_{j=0}^{\infty}\alpha_{ij}L^j$. We can normalize so that the time endowment of one type of individuals is one, and we shall actually normalize both to have the same time endowment, which can be interpreted as equal numbers of the two types in the economy. Thus, we let $n_{it} = 1-\ell_{it}$ be the amount of nonsleeping time allocated to market activity.

The lag distributions $\alpha_i(L)$ determine the degree to which leisure is intertemporally substitutable. The weights α_{ij} are assumed positive and, without loss of generality, restricted to sum to one. This lag distribution is assumed to be defined by two parameters, α_{i0} and η_i, which are the weight on current leisure and one minus the ratio of weights $\alpha_{i,j+1}/\alpha_{ij}$ on past leisure choices in current utility. With these restrictions, and defining the variable $a_{it} = \Sigma_{j=1}^{\infty}(1-\eta_i)^{j-1}n_{i,t-j}$, the distributed lags have the following representations:

$$\alpha_i(L)\ell_{it} = 1 - \alpha_{i0}n_{it} - \eta_i(1-\alpha_{i0})a_{it}, \text{ and}$$

$$a_{i,t+1} = (1-\eta_i)a_{it} + n_{it}, \quad i = 1,2. \tag{3.5}$$

The variables a_{it} summarize the effects of past leisure choices on current and future preferences. If $n_{is} = n_{it}$ for all $s \le t$, then the distributed lag is simply $1 - n_{it}$.

The utility functions are assumed to have the form

$$u_i(c_{it}, \alpha_i(L)\ell_{it}) = \frac{1}{\gamma}[c_{it}^{\mu_i}(\alpha_i(L)\ell_{it})^{1-\mu_i}]^{\gamma}, \; i = 1,2,$$

where γ is less than one but different from zero. If the sum in the square brackets is viewed as a composite commodity, then the constant relative degree of risk aversion is $1-\gamma$. In this section, we emphasize that the two utility functions can be characterized by different share parameters μ and lag distributions $\alpha(L)$, say due to differences in productivity in the home as well. In the main example in Section VI, however, I shall assume that the two utility functions are identical.

The main source of randomness in this model is the technology shock λ_t. It is assumed to be the sum of two unobserved components,

$$\lambda_t = \lambda_{1t} + \lambda_{2t}, \tag{3.6}$$

where λ_{1t} is first-order autoregressive with parameter near one:

$$\lambda_{1,t+1} = 0.95\lambda_{1t} + \varepsilon_{1t}, \tag{3.7}$$

and λ_{2t} is transitory:

$$\lambda_{2,t+1} = \varepsilon_{2t}. \tag{3.8}$$

Finally, the individual observes at the beginning of period t a noisy indicator π_t of λ_t:

$$\pi_t = \lambda_{1t} + \lambda_{2t} + \varepsilon_{3t}. \tag{3.9}$$

The shocks ε_{it} are independent and normal with variances σ_i^2. Kydland and Prescott (1982) describe in detail how conditional forecasts of λ_{1t} and λ_{2t} are determined, given past observations.

IV. MOTIVATION FOR THE UTILITY FUNCTION

In addition to skill differences, a key assumption of the model of particular relevance to employment fluctuation is the non-time-separable utility function which admits greater intertemporal substitution of leisure. The potential importance of this assumption was first suggested in the work of Lucas and Rapping (1969). As Barro and King (1982) demonstrated, however, the standard time-separable function can also in general be consistent with large percentage employment fluctuation associated with relatively small wage fluctuation. Their result is of little help in this context, however. It is clear that we are not allowed a great deal of freedom in choosing parameter values if we want the utility function to be consistent with the observations. Labor economists have found that the average long-run fraction of nonsleeping time spent in market activity is almost one-third. As we shall see, this suggests that the parameter μ cannot be far from this value. Also, studies of magnitudes of risk premia suggest that the utility function should not be too close to linear. The degree of risk aversion associated with the logarithmic function is probably a lower bound for what can be considered realistic.

When both utility specifications are restricted in this fashion, the time-separable formulation is consistent with a labor-supply elasticity of up to 1.5 on a quarterly basis, while the nonseparable function yields elasticities of the order of three to four, depending upon α_0 and μ, say, in ranges of 0.4 to 0.7 for α_0 and 0.1 to 0.4 for μ. This was demonstrated in Kydland (1983b) in the context of a model of a hypothetical infinitely-lived individual facing an exogenous process for the wage characterized by serially independent stochastic deviations from a constant permanent wage.[12] The individual is free to borrow or lend at a constant interest rate equal to his rate of time preference, and the current-period budget constraint is

$$A_{t+1} = (1+r)(A_t + w_t n_t - c_t), \tag{4.1}$$

where A_t denotes net real assets at the beginning of period t and is zero on the average. If one were free to reduce the share parameter μ and/or choose values of the risk-aversion parameter γ close to one, then much larger supply elasticities would be implied by the time-separable function as well.

Another point to note about the utility function in our model is that it is a Cobb-Douglas-type function which implicitly assumes unitary elasticity of substitution between consumption and leisure. To see whether this is a desirable restriction, consider the more general current-period utility function

$$\frac{1}{\gamma}[\mu c_t^{-\rho} + (1 - \mu)(\alpha(L)\ell_t)^{-\rho}]^{-\gamma/\rho},$$

where $-1 < \rho < \infty$. Let this be an individual in the same situation as described above, that is, whose current-period budget constraint is (4.1), and whose average consumption is $c = wn$, where variables without subscripts denote long-run or steady-state values. We wish to determine long-run hours worked, n, obtained by setting the wage shock at its mean of zero in every period.

Since the steady state is obtained by solving a deterministic problem, the value of γ does not matter and may as well be set equal to one for the

[12]Decision rules were computed by methods analogous to those described for the aggregate case in the next section. What is reported as the short-run labor-supply elasticity is the coefficient of the labor-supply decision rule with respect to the transitory wage rate and evaluated as an elasticity at the long-run level.

time being. Letting ζ be the Lagrange multiplier for the infinite-horizon budget constraint, the first-order conditions with respect to consumption and leisure are

$$\mu(G_t/c_t)^{1+\rho} = \zeta, \text{ and}$$

$$(1-\mu) \sum_{j=0}^{\infty} \beta^j \alpha_j (G_{t+j}/(\alpha(L)\ell_{t+j}))^{1+\rho} = \zeta w_t,$$

where $G_t = [\mu c_t^{-\rho} + (1-\mu)(\alpha(L)\ell_t)^{-\rho}]^{-1/\rho}$. In the steady state, $c_t = c$, $\ell_t = \ell$, and $w_t = w$ for all t. Using also the facts that the α_j sum to one, that $\sum_{j=0}^{\infty} \beta^j \alpha_j = (\alpha_0 r+\eta)/(r+\eta)$, and that $\ell = 1 - n$, these expressions can be written as

$$\mu(G/c)^{1+\rho} = \zeta, \text{ and}$$

$$(1 - \mu) \frac{\alpha_0 r+\eta}{r+\eta} (G/(1-n))^{1+\rho} = \zeta w.$$

Eliminating ζ and solving for n, one obtains the expression

$$n = \left[1+\left(\frac{1-\mu}{\mu} \frac{\alpha_0 r+\eta}{r+\eta} \right)^{1/(1+\rho)} w^{\rho/(1+\rho)}\right]^{-1}.$$

At the aggregate level, we want long-run labor supply to be independent of the long-run wage rate w. This is the case when $\rho = 0$, which is the special case of a Cobb-Douglas function. This is the reason that this function was used in Kydland and Prescott (1982) rather than the more general CES function, and we shall continue to use it here for the same reason.

Returning to our Cobb-Douglas formulation, we see that for the special case of time-separable utility ($\alpha_0 = 1$) we have $n = \mu$. In general, if the depreciation rate η is substantially larger than r, then n is very close to μ.

The two-parameter specification of the relative dependence of current utility on current and past leisure choices also warrants discussion. In Kydland and Prescott (1982), the values $\alpha_0 = 0.5$ and $\eta = 0.1$ were used. This means that the weight on current leisure ℓ_t is 0.5, while a total weight of 0.5 is distributed across past leisure choices starting with 0.05

on ℓ_{t-1}, 0.045 on ℓ_{t-2}, and so on. With the big drop at a rate of 0.9 from ℓ_t to ℓ_{t-1}, and then at a rate of 0.1 from then on, this weight distribution could obviously not be approximated by a one-parameter distribution.

A way to think about the dependence of current utility on past leisure choices is in the context of household production. Consider the possibility that a nonseparable utility function of the form above is a stand-in for a situation in which part of nonmarket activity either adds to or maintains a generally unobservable durable, the services of which are an argument of the utility function. One can imagine several possibilities. The utility of services provided by durables in the form of market goods (such as the home with related durables, cars, etc.) may depend on time input. In some cases, hiring somebody else's time can be an alternative to certain forms of one's own time input. In other cases, as in the production of "high-quality" children, parents have family-specific abilities that make them not easily substitutable. Once the decision to have a child has been made, there is presumably an intention or even commitment to spending a fair amount of time with them, although some degree of lumpiness of that time is acceptable.[13] If both parents work hard for a while in response to temporarily high wages, then the marginal product of at least one of them spending more time in the home rises. Other, generally less observable, durables (e.g., health) may be important as well.

Consider the simplest case and assume that a portion of nonmarket time contributes to the accumulation of a home durable whose stock at time t we shall denote by d_t. Thus, total time (or its nonsleeping portion) can be allocated as follows:

$$T = n_t + \ell_{1t} + \ell_{2t},$$

where n_t is market activity, and ℓ_{2t} results in accumulation of the durable as follows:

$$d_{t+1} = (1 - \eta)d_t + \ell_{2t}.$$

Current utility is a function of consumption of market goods c_t, "pure" leisure ℓ_{1t}, and (the services of) d_t. The behavioral implications of the

[13] Allowing the timing of children to be an economic decision may play a role as well, although I am abstracting from that possibility here.

nonseparable utility function above are equivalent to those of the special case of the present structure in which a fixed proportion of nonmarket time is spent on producing the durable, and ℓ_{1t} and d_t are perfectly substitutable in preferences. Thus, the role of the assumption that the weight on current leisure, α_0, is free and generally substantially larger than the other weights is to allow the presence of leisure in the form of ℓ_1 in addition to the leisure stock.

An alternative specification represents the opposite extreme on the production side in the sense of letting the two forms of nonmarket activity be perfectly substitutable, but with less substitutability in preferences. In this case, the steady-state properties can be made equivalent to those of the nonseparable function above, but the dynamic properties will not be exactly alike.

While there is at least one formulation of home production and preferences which is behaviorally equivalent to a utility function in which the intertemporal nonseparability is characterized by our two parameters, this discussion also makes it clear that, in general, that particular form must be viewed as an approximation. For some home production formulations, the behavior is going to be as if the weights on past leisure in the current utility function vary slightly over time. The general declining pattern of the weights will be maintained, however, and, even as a basis for understanding individual behavior, the parsimonious two-parameter formulation may still be a reasonable approximation. This may be the case also if market goods are an input along with time in the production of the durable. While I find it unlikely that one would want to consider anything other than the parsimonious two-parameter version for aggregate analysis, such insights on the nature of the weight distribution could be particularly useful in understanding microbehavior, as in panel data.

Various empirical studies use data that are available on a yearly basis only. This is so in studies using the Michigan Panel Study of Income Dynamics[14] and also in studies of aggregate behavior such as Lucas and Rapping (1969). A potentially important issue for this type of model is time aggregation. If, for example, one looks at the impulse-response function for labor supply associated with a positive transitory wage change in period t, there is a relatively large contemporaneous effect on employ-

[14] See, e.g., Heckman and MaCurdy (1980), MaCurdy (1981), and Hotz, Kydland, and Sedlacek (1982).

ment. In period t+1, however, there is a sizable negative effect, and then the response function moves steadily back towards the long-run level from below, although for large depreciation rates η it would generally go above the long-run level in period t+2 and oscillate from then on. It is reasonable to think that when four quarters are added or averaged to yield yearly observations, then behavior on the basis of a nonseparable utility function will result in data that resemble more closely the observations generated from a time-separable function.

Some have argued that there are severe restrictions on the extent to which individuals can adjust their hours or move in and out of the labor force due to contracts, implicit commitments, adjustment costs, or for other reasons. Such arguments are likely to work in the opposite direction, that is, play a bigger role the shorter the period length is. If they are valid, then certainly the month and perhaps even the quarter would be too short to get the intertemporal substitution effects that result from the nonseparable utility function. If the nature of the durable entering the home-production function as described above is such that half-a-year or a year is a reasonable period length in our utility function, then it is not inconceivable that monthly data could still look as if generated by a cost-of-adjustment model and thus presumably result in a negative estimate for the weight on lagged leisure. In our formulation, negative weights are certainly theoretically possible (by making $\alpha_0 > 1$). We have ruled out this possibility a priori, however, for it would result in model properties that are inferior to those implied by the time-separable specification.[15]

V. STEADY STATE AND COMPUTATION OF EQUILIBRIUM

To determine equilibrium processes for the model in Section III, I exploit the well-known connection between competitive equilibria and Pareto

[15]The empirical results in Eichenbaum, Hansen, and Singleton (1984) are interesting in this context. They find, using monthly aggregate data, and assuming a truncated lag distribution for leisure with weights only on current and last month's leisure choices, that the estimated weight on lagged leisure is indeed negative, although when they use methods that are more robust to measurement errors in the wage rate, the sign turns positive. It should be noted that, for the data series they use, what corresponds to the parameter μ above comes out to be only about one-sixth.

optima. In particular, under conditions satisfied for this model, any Pareto optimum can be supported as a competitive equilibrium with redistributions. With homogeneous agents, there is a unique optimum. When there are two types, we can weight the two utility functions, and each pair of relative weights corresponds to a Pareto optimum. Thus, a particular equilibrium is found by maximizing a weighted sum of the two utility functions, subject to constraints (3.1)-(3.9), with weights ψ and $1-\psi$ on the utility of skilled and unskilled workers, respectively. The choice of ψ will be discussed in Section VI.

The aim is to determine the variance-covariance properties of the model of the aggregate economy described in Section III and to contrast them with data on the post-war United States economy. Due to the form of the utility function and the nonlinearity of the resource constraint (3.1), this is infeasible for the exact form of the model.[16] Instead, we shall study the approximate economy found by making a quadratic approximation around the steady state of the exact model. For that reason, we next turn to the determination of the steady state.

The steady state or rest point is found by setting λ_t equal to its unconditional mean λ in every period. The steady-state properties that follow from the production side are the same as in Kydland and Prescott (1982), with the homogeneous hours worked now replaced by the efficiency units n_e. Thus, I shall simply report these relations and refer to that paper for more detail of their derivation.

The steady-state interest rate is $r = (1 - \beta)/\beta$, and the steady-state price of productive capital relative to consumption goods is $q = \Sigma_{j=1}^{J}\phi_j(1 + r)^{j-1}$. The capital-inventory ratio is given by

$$y = \left[\frac{(r+\delta)\sigma q}{r(1-\sigma)} \right]^{1/(\nu+1)} k \equiv b_1 k,$$

and the steady-state capital-labor ratio is

[16] This will be a problem for almost any aggregate model with detailed specification of both technology and preferences. Even if one is willing to start off with a quadratic utility function, nonlinearities will come in through the budget or resource constraint, either because of the production function or due to the presence of terms involving a price, to be determined in equilibrium, multiplying a state or decision variable. There are of course exceptions, such as the model in Sargent (1979) in which utility is assumed to be linear in consumption.

$$k = \left[\frac{(1-\theta)(1-\sigma)}{q(r+\delta)} b_2^{-(1-\theta+\nu)/\nu} \right]^{1/\theta} \lambda^{1/\theta} n_e \equiv b_3 \lambda^{1/\theta} n_e,$$

where $b_2 = 1 - \sigma + \sigma b_1^{-\nu}$. Steady-state output as a function of n_e is $f = b_2^{-(1-\theta)/\nu} b_3^{1-\theta} \lambda^{1/\theta} n_e \equiv b_4 \lambda^{1/\theta} n_e$. In the steady state, net investment is zero, and therefore

$$c_1 + c_2 = f - \delta k = (1 - \delta b_3/b_4) b_4 \lambda^{1/\theta} n_e,$$

where consumption's share of total steady-state output is $1 - \delta b_3/b_4$.

Turning to the consumer side, I here assume for simplicity that $\mu_1 = \mu_2 = \mu$. Letting ζ be the Lagrange multiplier for the budget constraint and w_{it} the real wage of an individual of type i, the first-order conditions for all t are

$$\psi \mu G_{1t}^{\gamma} c_{1t}^{-1} = \zeta,$$

$$(1 - \psi) \mu G_{2t}^{\gamma} c_{2t}^{-1} = \zeta,$$

$$\psi(1-\mu) \sum_{j=0}^{\infty} \beta^j \alpha_{1j} G_{1,t+j}^{\gamma} (\alpha_1(L) \ell_{1,t+j})^{-1} = \zeta w_{1t}, \text{ and}$$

$$(1-\psi)(1-\mu) \sum_{j=0}^{\infty} \beta^j \alpha_{2j} G_{2,t+j}^{\gamma} (\alpha_2(L) \ell_{2,t+j})^{-1} = \zeta w_{2t},$$

where $G_{it} \equiv c_{it}^{\mu} (\alpha_i(L) \ell_{it})^{1-\mu}$, $i = 1,2$. In the steady state, through similar manipulations as in Section IV, these expressions become

$$\psi \mu G_1^{\gamma} = \zeta c_1, \tag{5.1}$$

$$(1 - \psi) \mu G_2^{\gamma} = \zeta c_2, \tag{5.2}$$

$$\psi(1-\mu) \frac{\alpha_{10} r^{+n_1}}{r+n_1} G_1^{\gamma} = \zeta w_1 (1-n_1), \text{ and} \tag{5.3}$$

$$(1-\psi)(1-\mu)\ \frac{\alpha_{20}r+\eta_2}{r+\eta_2}\ G_2^{\gamma} = \zeta w_2(1-n_2). \tag{5.4}$$

Combining (5.1) and (5.2), we obtain

$$\psi G_1^{\gamma} c_2 = (1-\psi) G_2^{\gamma} c_1. \tag{5.5}$$

Conditions (5.2) and (5.4) yield

$$(1-\mu)\ \frac{\alpha_{20}r+\eta_2}{r+\eta_2}\ c_2 = \mu w_2(1-n_2). \tag{5.6}$$

Finally, using conditions (5.2) and (5.3), we obtain

$$\psi(1-\mu)\ \frac{\alpha_{10}r+\eta_1}{r+\eta_1}\ G_1^{\gamma} c_2 = (1-\psi)\mu G_2^{\gamma} w_1(1-n_1). \tag{5.7}$$

The real wages, which in equilibrium must be equal to the respective marginal products, are

$$w_1 = f_{n_1} = \frac{\omega\theta}{n_e} f = \omega\theta b_4 \lambda^{1/\theta}, \text{ and}$$

$$w_2 = f_{n_2} = \frac{\theta}{n_e} f = \theta b_4 \lambda^{1/\theta}.$$

Then (5.6) and (5.7) imply

$$\psi\ \frac{\alpha_{10}r+\eta_1}{r+\eta_1}\ (1-n_2) G_1^{\gamma} = (1-\psi)\omega\ \frac{\alpha_{20}r+\eta_2}{r+\eta_2}\ G_2^{\gamma}(1-n_1).$$

Combining this expression with (5.5) yields the condition

$$\frac{c_1}{c_2} = \omega\ \frac{(\alpha_{10}r+\eta_1)(r+\eta_2)}{(\alpha_{20}r+\eta_2)(r+\eta_1)}\ \frac{1-n_1}{1-n_2}\ . \tag{5.8}$$

It is illustrative to consider the case of $\alpha_{10} = \alpha_{20} = \alpha_0$ and $\eta_1 = \eta_2$

$= \eta$. For that case, equation (5.8) simplifies to $c_1/c_2 = \omega(1-n_1)/(1-n_2)$. Using this equation and the steady-state budget constraint, $c_1 + c_2 = f - \delta k$, we can write

$$c_2 = (1-n_2)(f-\delta k)/(\omega+1-n_e). \tag{5.9}$$

Equation (5.6) then becomes

$$\omega n_1+n_2 = (\omega+1)/\left[1+ \frac{1-\mu}{\mu} \frac{\alpha_0 r+\eta}{\theta(r+\eta)} (1-\delta b_3/b_4)\right]. \tag{5.10}$$

Thus, total steady-state hours measured in efficiency units are given by an expression equivalent to the one for steady-state hours in Kydland and Prescott (1982). Finally, given equations (5.9) and (5.10), equation (5.7) determines n_1, which in turn determines n_2 and c_2 through (5.10) and (5.8). Consumption c_1 by the skilled is then given by the resource constraint.

If we compare with the expression for n in Section IV for the case of $\rho = 0$, we see similarity, except for the appearance of the terms $1 - \delta b_3/b_4$ and θ. The first is the steady-state consumption-output ratio, and the second is labor's share of output. Thus, the ratio of these two terms corresponds to aggregate consumption in relation to labor income. In the example in Section IV, steady-state c was equal to wn, implying this ratio was one. In aggregate data, the average value of this ratio is larger than one. For that reason, in spite of a value for μ of one-third, the implied value for n in Kydland and Prescott (1982) was 0.308. In the present model in which both n_1 and n_2 have to be determined, n_1 typically turns out to be about the same as μ, while n_2 is somewhat smaller.

Given the steady state, the remaining steps in the computation of equilibrium are similar to those described in Kydland and Prescott (1982). A difference is that, in this model, we need to distinguish between consumption by the two skill groups. To eliminate the nonlinearity in the resource constraint, I substitute $f(\lambda, k, n_e, y) - x - c_1$ for c_2 in the weighted utility function and then make a quadratic approximation around the model's rest point. As the remaining constraints are linear, it is now farily straightforward to determine recursively the equilibrium decision rules for the approximate economy.[17]

The decision variables are n_{1t}, n_{2t}, s_{Jt}, y_{t+1}, c_{1t}, and c_{2t}, of which

c_{2t} is determined from the resource constraint. The distinction between a_{1t} and a_{2t} adds another state variable. The equilibrium can be represented by a linear stochastic system of difference equations consisting of constraints (3.2)-(3.9), the decision rules which are functions of a state vector that includes conditional expectations of the unobserved permanent and transitory technology shocks, and the linear relations for updating these conditional expectations on the basis of the most recent observations.

VI. PROPERTIES OF THE MODEL

The purpose here is not to test the new model to the same extent that was done for the model in Kydland and Prescott (1982). Rather, the intention is to illustrate what an abstraction with both skilled and unskilled workers can do relative to the representative-agent model. The parameters that are common for the two models will therefore remain unchanged. The parameters of the utility functions (assuming a quarterly model) are: $\beta = 0.99$, $\gamma = -0.5$, $\mu = 0.33$, $\alpha_0 = 0.5$, and $\eta = 0.1$. The technology parameters are $\nu = 4.0$, $\theta = 0.64$, $\sigma = 0.28 \times 10^{-5}$, $\phi_i = 0.25$, $i = 1,\ldots,4$, $\delta = 0.025$, and $\bar{\lambda} = 1.0$. Finally, the shocks have standard deviations $\sigma_1 = 0.0090$, $\sigma_2 = 0.0018$, and $\sigma_3 = 0.0090$. The sum of the three variances is chosen such that the average standard deviation of output is 1.8 percent as in the data. Thus, only two relative variances are free parameters. Kydland and Prescott used the statistics for the cyclical components of the United States economy that were computed in Hodrick and Prescott (1980) for a period ending in 1979:2. I shall here instead refer to the updated statistics presented in Prescott (1983) for a 116-quarter period ending in 1982:4.

In my model, the two real wage rates are proportional to average productivity. The theory, however, does not require that compensation and delivery be contemporaneous. Also, Stockman (1983) finds evidence of aggregation bias in the real wage due to variable weighting by hours. Thus, even if the average product is close to the marginal product of labor, it is not surprising if the productivity and real wage series have

[17] The details are the same as described in Kydland and Prescott (1982, pp. 1357-59).

different properties. In fact, the former may be a better measure of compensation. Prescott (1983) finds that the relative percentage standard deviation of cyclical hours is 1.7 (all standard deviations are based on percentage deviations relative to trend), while it is 1.0 for productivity and 1.2 for real compensation per hour in manufacturing. In the model, the standard deviation of productivity is generally on the order of 0.8 to 0.9, and it is probably unreasonable to think that the standard deviation of hours should remain as high as in the data in order for the model to be successful. Instead, I shall use the ratio of the standard deviation of cyclical hours to that of productivity (hereafter referred to as the HP-ratio), which is 1.7 in the data, as a measure of what the model should be close to. I shall also pay attention to the correlation between cyclical productivity and output. The remaining statistics used in Kydland and Prescott (1982) for comparing the model with the data change little for the model versions considered in this section and will therefore not be reported.

The two-skill model in principle does not have new free parameters. Given that the labor force is evenly distributed across skills, it should be possible to determine the relative efficiency parameter ω fairly accurately from data, for example from the PSID. Then, alternative weights, ψ and $1-\psi$, on the utility functions yield different long-run hours worked for the two skill groups. It should also be possible to quantify this difference from microdata.

Rather than attempting to do that, I shall illustrate the model by using a figure of 2.0 for ω and weight the skilled workers' utility according to their relative stocks of human capital for the production of market goods, that is, let $\psi = 0.667$. For these parameter values, the skilled workers work on the average only 20 percent more than the unskilled. This difference is clearly on the low side, especially if a large proportion of the females belong in the group that is relatively less skilled for market production. The increase in HP-ratio was from 1.20 in Kydland and Prescott to 1.39 when the two-skill feature was introduced. With a finer division into three or four skill groups, a larger ratio can be expected. Thus, this model feature alone appears capable of making up about half the difference between the data and the original model.

It is interesting to note that, for these equilibria, the implied long-run ratio of c_1 to c_2 is different from the ratio of labor incomes. In fact, the unskilled consume more than their share. Given the magnitudes of public consumption and transfers as a percentage of private consumption, this is not unrealistic, since these items surely benefit the unskilled the most. Some public consumption is probably a close substitute for private consumption. If we could put a reliable figure on c_1/c_2, then it appears from equation (5.8) that we could let one of the parameters of the utility functions differ across skill groups without adding free parameters.

It is likely that much of this reallocation takes place within the household. In that case, however, it is probably unrealistic to assume that utility of the two types of leisure is strongly separable, as we have implicitly done. An interesting abstraction would be one of an economy consisting of a large number of households, each with two individuals who have different time endowments measured in efficiency units. Utility would then be a function of three variables, namely, total household consumption and the two leisure variables.[18] The household production literature may provide guidance and appropriate restrictions in modeling preferences. For now, this will remain a topic for future research.

So far, the ratio of the real wages of the two groups has remained constant and equal to ω in every period. This is inconsistent with empirical findings, reported, for instance, in Reder (1962) that the wage difference between skilled and unskilled workers is countercyclical. A possible reason is tied in with technological change. Many skilled workers (e.g., engineers) have specialized skills which easily become obsolete in periods of rapid technological progress. On the other hand, they are generally fairly adaptable and can easily adjust to different tasks, perhaps requiring slightly less skill. This story suggests that it is not unreasonable to make the parameter ω a function of the technological shock λ_t. If $\bar{\lambda}$ is equal to one, say, the simplest way would be to let $\omega_t = [1 + \tau(\lambda_t - 1)]\bar{\omega}$, where $\tau < 0$. This new parameter is not really free, either. For $\tau = 0$, the variability of n_{2t} relative to that of n_{1t} is close to the ratio of steady-state n_1 to n_2. With a negative τ, long-run n_1 and n_2 remain unchanged, but n_{2t} is now more variable relative to n_{1t} than in the case of $\tau = 0$. This difference in variability across the skill groups should be quantifiable with a reasonable degree of accuracy. If, for the purpose of our illustration, we continue to let $\omega = 2.0$, then a value of τ such that the standard deviation of the variation in ω_t relative to its steady state is a quarter of a percent increases the variability of hours

[18] See Hanoch (1980) and Johnson and Pencavel (1984).

relative to productivity from 1.39 to 1.67. The percentage fluctuation of n_{2t} is more than twice as large as for n_{1t}.

The correlation between cyclical productivity and output is still too high, even for the last version. Its mean under repeated sampling from the model is 0.78, with a standard deviation of 0.03. For the United States data, as reported in Prescott (1983), the cross-correlation of cyclical real output with productivity is 0.34, while the cross-correlation of output with real compensation per hour is 0.63. Much of this discrepancy between the model and the data can be due to measurement error in aggregate hours figures, which are difficult to measure accurately. If we include in the model a measurement error for hours which is independent over time, then the variation of hours as well as the correlation between output and productivity are reduced, but by a relatively greater magnitude for the latter. Part of the reason for this high correlation in the model is probably also due to the way the technology shock enters multiplicatively, affecting the entire capital stock already in place. An alternative would be to have at least some of the technological change restricted to newly built capital.

This abstraction has the two types of labor inputs entering the production function very simply. Once adjustments are made for differences in efficiency, the two inputs are perfect substitutes. A natural alternative is to allow for more interesting and realistic trade-offs by making them less substitutable. This can be done, for instance, by replacing the term n_e^{θ} in the production function by a CES function in n_1 and n_2. Since the marginal product of each labor input will vary inversely with its quantity, the equilibrium wage differential will also vary over the cycle. If, however, the model is to be consistent in equilibrium with the observation that unskilled labor fluctuates more, then these wage differences will move in the wrong direction over the cycle unless the elasticity of substitution increases in booms and declines in recessions. This movement of the substitution elasticity is indeed consistent with the explanation Reder (1962) gives for the relative variation in employment of skilled and unskilled workers. Another possibility is to model the interaction between labor inputs and capital so that the two partial elasticities of substitution are different as in the theory underlying Rosen's (1968) estimates. The empirical production-function literature should provide guidance on which of these avenues is more promising and on how to restrict the parameters.

VII. FURTHER AGGREGATION ISSUES

The results in this paper may, on the face of it, appear quite damaging to the representative-agent model. One has to remember, however, that allowing for different skills made little difference in the model characteristics other than the ones directly associated with employment. Thus, there is a sense in which one can continue to use that model, with hours interpreted as efficiency units, knowing that there is a measurement error in the hours data relative to the abstraction. This approach appears to yield variance-covariance properties approximately equal to the ones obtained with explicit differences in skills. If for instance we want to extend the model to examine separately the role of money or consumer durables for the business cycle, or perhaps if we want a more detailed specification of technological change, the representative-agent abstraction may provide what we need for that purpose with regard to the way labor-leisure decisions are made.

There may be other reasons, however, for labor economists to be uncomfortable with this model. In order for it to be consistent with the observations, it is essential that leisure in adjacent periods be good substitutes. This is accomplished by letting current utility depend on past leisure choices. In theory, of course, such dependence could also reflect complementarity, as with habit formation, for different specifications of the lag structure. Neither that model nor the standard time-separable utility function is consistent with aggregate observations, at least not at this level of abstraction. This statement is also supported by the estimates in Lucas and Rapping (1969).

This finding is in sharp contrast with the intertemporal-substitution elasticities that have been estimated on the basis of panel data.[19] In trying to reconcile these differences, there are several possibilities. There are reasons why the microestimates may be biased downwards. We have already mentioned the likelihood that there are sizeable measurement errors. If the errors in the hours and wage observations are highly negatively correlated, as is certainly the case, this will reduce the degree of intertemporal substitution in the data. There is also the problem that, even if the average wage rate is properly recorded, it may

---

[19]See for example Heckman and MaCurdy (1980) and MaCurdy (1981).

still, as I suggested earlier, be an imperfect measure of compensation for the hours supplied in that period. This problem is likely to be more severe at the individual than at the aggregate level.

Empirical studies using panel data have often tried to account for heterogeneity in interesting ways at the expense of having to employ very simple utility functions, which are generally separable both across and within periods, in order to keep the models tractable. As Kydland (1983b) argues, the fact that these specifications are used may bias the short-run labor-supply elasticities downwards. Another problem is that the micro-estimates have generally been based on data for prime-age males, which is not where we expect to see the most variation.

A possibility that has been suggested to me by labor economists is that their estimates are not too far off the mark, but that the difference in properties at the aggregate level results from aggregation in the presence of heterogeneity. This idea has some tradition in the labor-economics literature.[20] For example, in studying female labor supply, it has been pointed out by Heckman (1979) that "if women differ in their propensity to work, if differences are stable over time, and if the differences cannot be directly measured, an observed relationship between current work choices and past participation can arise solely as a consequence of heterogeneity."

Perhaps a more interesting possibility is to consider fixed costs of working. As demonstrated in Cogan (1981) and Heckman and MaCurdy (1981) within a static model, such fixed costs give rise not only to a reservation wage but also to a level of "reservation" hours such that the individual will either work at least that many hours or will not work at all.[21] I have not seen this model worked out in a dynamic context. There, of course, one would have to take a stand on whether the fixed cost is incurred only in the period in which one changes from zero to positive hours, or whether the cost is incurred in every period (such as the time and money cost of travelling to work). It seems clear that the former, which is really a cost-of-adjustment model, would not yield the observed aggregate pattern.

[20]See Heckman and Willis (1977) and Heckman (1979).

[21]Hanoch (1980) and Oi (1962) have also emphasized the importance of fixed costs for employment decisions.

With a fixed cost in every period in which one works, there would certainly be a great deal of variation for those who switch between zero and a large number of hours. Whether this is sufficient to yield the aggregate observations, say with a time-separable utility function, is a different matter. One could investigate this possibility by constructing a dynamic fixed-costs model in which there is a given distribution of wages across individuals in every period, say with a common component and an individual-specific component, both of which move according to a stochastic process. Workers may also be heterogeneous in terms of fixed costs. Analysis of such a model should enable one to find out whether it can produce seemingly high intertemporal substitution for the average or the sum across individuals.[22]

Not knowing the answer on this issue, we can still entertain the possibility that we shall eventually find that, relative to what is needed in order to explain individual behavior, a completely different utility function is needed in order to be consistent with aggregate observations within a representative-agent framework. I will argue that this framework can still be very useful for constructing models of artificial economies to help us understand recurrent business cycles. Such models will naturally have to abstract from many things in reality, and it is not necessary to be able to aggregate from individual behavior, not even as a close approximation, in order for them to serve their purpose.

It is important not to forget what this purpose is. While we are still groping for the right model elements that will help us understand the nature of business cycles, nobody (I hope) would seriously propose to use these models for detailed policy analysis. That is still far down the road. And representative-agent models will probably never be suitable for evaluating policy issues such as the cost of a negative-income-tax experiment.

Lucas (1980) argues that we need to specify our models in such a way that the number of free parameters is small, for example by using parameter values from microobservations. If microbehavior is substantially different from the implied aggregate behavior, the main problem in using a representative-agent framework is that what otherwise could have been a source of parameter values may now be considerably less helpful for that purpose.

---

[22] A related issue may be the possible presence of borrowing constraints as suggested and analyzed in Scheinkman and Weiss (1983).

VIII. CONCLUDING REMARKS

I have attempted, within an aggregate dynamic equilibrium model of the business cycle, to take account of the observation that relative hours' fluctuations across skill groups display differences that are quantitatively important. Using the results in Kydland and Prescott (1982) as a bench mark, I have demonstrated the potential for the new model elements to improve the fit of the model to the data. Steps towards testing the theory were suggested without carrying them out in detail. I showed how, in principle, the extension to two skills can be made without adding new free parameters. This is also the case when one considers fluctuation in the wage difference between the groups. A serious test would probably require further work on finding an appropriate specification of the production function and perhaps also of preferences, and our results so far are only tentative. I argue, however, that in many cases, depending on the purpose of the research, going beyond the homogeneous-agent framework may not be essential for understanding business-cycle phenomena.

In this paper, I have obviously abstracted from many things that are relevant for employment variation, for example the role of contracts.[23] I did mention their possible influence on the time pattern of compensation relative to effort.[24] It remains an important research topic to determine the importance of contracts for aggregate fluctuations.

The discussion of differences in labor-supply elasticities between micro and aggregate studies illustrates the importance of maintaining a dialogue between micro and macroeconomists modelling labor markets. A concern about why one's results do not appear to be consistent with the results at alternative levels of aggregation should contribute to improving our understanding of the business cycle.

---

[23] See Azariadis (1976), Fischer (1977), and Taylor (1980) for examples of issues in relation to the role of contracts.

[24] See Hall and Lilien (1979).

References

Altug, S.

(1983) Gestation Lags and the Business Cycle. Working Paper, Carnegie-Mellon University. Presented at the NBER Macro Conference, Cambridge, 1984.

Azariadis, C.

(1976) On the Incidence of Unemployment, *Review of Economic Studies*, **43**: 115-25.

Barro, R.J.

(1976) Rational Expectations and the Role of Monetary Policy, *Journal of Monetary Economics*, **2**: 1-32.

_________ and King, R.G.

(1982) Time-Separable Preferences and Intertemporal-Substitution Models of Business Cycles. Working Paper, University of Rochester.

Becketti, S.

(1983) The Persistence of Nominal Shocks in a Particular Equilibrium model. Working Paper, University of California, Los Angeles.

Brock, W.A. and Mirman, L.

(1972) Optimal Economic Growth under Uncertainty: the Discounted Case, *Journal of Economic Theory*, **4**: 479-513.

Brunner, K., Cukierman, A., and Meltzer, A.H.

(1980) Stagflation, Persistent Unemployment and the Permanence of Economic Shocks, *Journal of Monetary Economics*, **6**: 467-92.

____

(1983) Money and Economic Activity, Inventories, and Business Cycles, *Journal of Monetary Economics*, **11**: 281-329.

Cass, D.

(1965) Optimum Growth in an Aggregative Model of Capital Accumulation, *Review of Economic Studies*, **32**: 233-40.

Clark, K.B. and Summers, L.H.
(1981) Demographic Differences in Cyclical Employment Variation, *Journal of Human Resources*, **16**: 61-79.

Cogan, J.F.
(1981) Fixed Costs and Labor Supply, *Econometrica*, **49**: 945-63.

Danthine, J.P. and Donaldson, J.B.
(1981) Stochastic Properties of Fast vs. Slow Growing Economies, *Econometrica*, **79**: 1007-33.

Debreu, G.
(1954) Valuation Equilibrium and Pareto Optimum, *Proceedings of the National Academy of Science*, **70**: 588-92.

Eichenbaum, M.S., Hansen, L.P., and Singleton, K.S.
(1984) A Time Series Analysis of Representative Agent Models of Consumption and Leisure Choice Under Uncertainty. Working Paper, Carnegie-Mellon University. Presented at the NBER Regional Research Meeting on Economic Fluctuations, Cambridge, 1984.

Fischer, S.
(1977) Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule, *Journal of Political Economy*, **85**: 191-205.

Hall, R.E.
(1980) Labor Supply and Aggregate Fluctuations. *On the State of Macro-economics*. Carnegie-Rochester Conference Series on Public Policy, **12**, (eds.) K. Brunner and A.H. Meltzer. Amsterdam: North-Holland.

__________ and Lilien, D.
(1979) Efficient Wage Bargains under Uncertain Supply and Demand, *American Economic Review*, **69**: 868-79.

Hanoch, G.

(1980) Hours and Weeks in the Theory of Labor Supply. *Female Labor Supply: Theory and Estimation*, (ed.) J.P. Smith. Princeton: Princeton University Press.

Hansen, L.P. and Singleton, K.J.

(1983) Stochastic Consumption, Risk Aversion, and the Temporal Behavior of Asset Returns, *Journal of Political Economy*, **91**: 249-65.

Heckman, J.J.

(1979) New Evidence on the Dynamics of Female Labor Supply. *Women in the Labor Market*, (eds.) C.B. Lloyd, E.S. Andrews, and C.L. Gilroy. New York: Columbia University Press.

_________ and MaCurdy, T.E.

(1980) A Life Cycle Model of Female Labour Supply, *Review of Economic Studies*, **47**: 47-74.

____

(1981) New Methods for Estimating Labor Supply Functions: A Survey, *Research in Labor Economics*, **4**. JAI Press.

_________ and Willis, R.J.

(1977) A Beta Logistics Model for the Analysis of Sequential Labor Force Participation by Married Women, *Journal of Political Economy*, **85**: 27-58.

Hodrick, R.J. and Prescott, E.C.

(1980) Post-war U.S. Business Cycles: An Empirical Investigation. Working Paper, Carnegie-Mellon University.

Hotz, V.J., Kydland, F.E., and Sedlacek, G.L.

(1982) Intertemporal Substitution and Labor Supply. Working Paper, Carnegie-Mellon University. Presented at the Annual Meeting of the American Economic Association, New York, 1982.

Johnson, T.R. and Pencavel, J.H.
(1984) Dynamic Hours of Work Functions for Husbands, Wives, and Single Females, *Econometrica*, **52**: 363-89.

Koopmans, T.C.
(1965) On the Concept of Optimal Economic Growth. *The Econometric Approach to Development Planning*, Chicago: Rand-McNally.

Kydland, F.E.
(1983a) The Role of Money in a Competitive Theory of Business Fluctuations. Working Paper No. E-83-10, Hoover Institution.

———
(1983b) Nonseparable Utility and Labor Supply. Working Paper No. E-83-16, Hoover Institution. Presented at the NBER Macro Conference Cambridge, 1983.

Kydland, F.E. and Prescott, E.C.
(1980) A Competitive Theory of Fluctuations and the Feasibility and Desirability of Stabilization Policy. *Rational Expectations and Economic Policy*, (ed.) S. Fischer. Chicago: University of Chicago Press.

Kydland, F.E. and Prescott, E.C.
(1982) Time to Build and Aggregate Fluctuations, *Econometrica*, **50**: 1345-70.

Long, J.B. and Plosser, C.I., Jr.
(1982) Real Business Cycles, *Journal of Political Economy*, **91**: 39-69.

Lucas, R.E., Jr.
(1972) Expectations and the Neutrality of Money, *Journal of Economic Theory*, **4**: 103-24.

———
(1975) An Equilibrium Model of the Business Cycle, *Journal of Political Economy*, **83**: 1113-44.

Lucas, R.E., Jr.
(1976) Econometric Policy Evaluation: A Critique. *The Phillips Curve and Labor Markets.* Carnegie-Rochester Conference Series on Public Policy, **1**, (eds.) K. Brunner and A.H. Meltzer. New York: North-Holland.

Lucas, R.E., Jr.
(1980) Methods and Problems in Business Cycle Theory, *Journal of Money, Credit, and Banking*, **12**: 696-715.

Lucas, R.E. Jr. and Prescott, E.C.
(1971) Investment Under Uncertainty, *Econometrica*, **39**: 659-81.

Lucas, R.E., Jr. and Rapping, L.A.
(1969) Real Wages, Employment, and Inflation, *Journal of Political Economy*, *77*: 721-54.

MaCurdy, T.E.
(1981) An Empirical Model of Labor Supply in a Life-Cycle Setting, *Journal of Political Economy*, **89**: 1059-85.

McCallum, B.T.
(1982) The Role of Overlapping-Generations Models in Monetary Economics. Carnegie-Rochester Conference Series on Public Policy, **18**, (eds.) K. Brunner and A.H. Meltzer. Amsterdam: North-Holland.

Mincer, J.
(1966) Labor-Force Participation and Unemployment: A Review of Recent Evidence. *Prosperity and Unemployment*, (eds.) R.A. Gordon and M.S. Gordon. John Wiley & Sons.

Oi, W.
(1962) Labor as a Quasi-fixed Factor, *Journal of Political Economy*, **70**: 538-55.

Prescott, E.C.

(1983) "Can the Cycle be Reconciled with a Consistent Theory of Expectations?" or, a Progress Report on Business Cycle Theory. Presented at the IMSSS Summer Workshop, Stanford University.

Prescott, E.C. and Mehra, R.

(1980) Recursive Competitive Equilibrium: the Case of Homogeneous Households, *Econometrica*, **48**: 365-79.

Reder, M.W.

(1962) Wage Differentials: Theory and Measurement. *Aspects of Labor Economics*. New York: National Bureau of Economic Research.

Rosen, S.

(1968) Short-Run Employment Variation on Class-I Railroads in the U.S., 1947-1963, *Econometrica*, **36**: 511-29.

Sargent, T.J.

(1979) *Macroeconomic Theory*. New York: Academic Press.

____

(1981) Interpreting Economic Time Series, *Journal of Political Economy*, **89**: 213-48.

____

(1982) Beyond Demand and Supply Curves in Macroeconomics, *American Economic Review*, **72**, Papers and Proceedings: 382-89.

Scheinkman, J.A. and Weiss, L.

(1983) Borrowing Constraints and Aggregate Economic Activity. Working Paper, University of Chicago.

Stockman, A.C.

(1983) Aggregation Bias and the Cyclical Behavior of Real Wages. Presented at the NBER Macro Conference, Cambridge, 1983.

Taylor, J.B.

(1980) Aggregate Dynamics and Staggered Contracts, *Journal of Political Economy*, **88**: 1-23.