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CYCLES AND NON-STATIONARY EQUILIBRIUM SEARCH*

by

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Introduction

There has never been agreement among economists regarding the causes of cycles and fluctuations in economic activity. There can be little doubt that extraneous shocks to the economy are a major source of such fluctuations. Nevertheless, in our view, it is important to have models in which cyclic activity arises as an inherent property of the equilibrium interaction between economic agents at the micro level. More specifically, we would like to know if it is possible that despite the absence of any shocks, a stationary environment exhibits a nonstationary time path as a consequence of the dynamic strategic interaction between the economic actors.

The persistence of endogenously determined oscillations in one market creates a nonstationary environment in related markets which may, in principle, respond by exhibiting cyclic behavior of their own. Moreover, the transmission of fluctuation from one market to another may generate cyclic behavior of the second market which persists long after the initial stimulus is gone, as has been shown, for example, by Rotemberg and Saloner (1986). Thus, using McCall's (this volume) terminology, once one market "vibrates" endogenously, the interrelationship between markets may transmit this vibration across the economy, leading to cyclical activity at the aggregate level. This line of reasoning is particularly appealing when the oscillation originates in a market whose effect on and ability to transmit vibrations to other markets is especially significant. An obvious candidate is the labor market.

Previous modelling efforts aimed at achieving endogenous fluctuations of the type discussed above have emphasized the role of self fulfilling prophecies. A brief and highly selective discussion of this literature is presented in section 2. Our focus in the remainder of the paper will be to present an example of an explicitly dynamic search equilibrium in an imperfect labor market in which workers search for profitable employment over time. The equilibrium displays cyclic patterns in both wage offers and the acceptance rate of workers (i.e., the incidence of unemployment). As will be shown, depending on the parameters of the model, in many cases the only equilibria consistent with wage dispersion in the model are cyclical. Thus the incidence of wage and employment cycles in our model are an inherent feature of the intertemporal optimization of agents and not a mere consequence of arbitrary, self fulfilling expectations.

The remainder of the paper is organized as follows. Section 2 presents a brief and non comprehensive look at a class of models exhibiting endogenous cyclical patterns as a consequence of self fulfilling beliefs. Section 3 discusses the general properties of nonstationary search equilibrium models. In section 4 we discuss a simple example of a cyclic search equilibrium in which cyclic behavior is a consequence of arbitrary, self fulfilling beliefs. In section 5 we demonstrate our main claim by deriving a cyclical search equilibrium in which the periodic fluctuations in wages and employment are a necessary and inherent feature of the dynamic interaction between firms and workers.

2. Cycles with self-fulfilling Prophecies

In this section we discuss models of endogenous business cycles which are a consequence of self fulfilling expectations. In models of this type, agents maintain essentially arbitrary but commonly shared expectations about the future course of the economy and, based on these expectations, take individually rational actions which in the aggregate serve to fulfill these expectations. Azariadis (1981), Cass and Shell (1983), Grandmont (1983) and Farmer and Woodford (1984), among others, demonstrate the existence of such equilibria in overlapping generations models.

Diamond (1982) derives such equilibria in the context of a matching model. Production opportunities arrive stochastically and are distinguished by different production costs. Potential trading partners arrive stochastically at a rate which is positively related to aggregate production in the economy. A successful trade is concluded only if one's partner has output in inventory. As the profitability of any particular project increases the more quickly a trade can be successfully completed, it follows that actual aggregate activity is determined by expectations about its extent. Diamond and Fudenberg (1986) have shown that this scheme can be extended to generate cyclic activity when traders correctly anticipate that the economy will alternate between optimistic ("boom") and pessimistic ("decline") phases. In a related vein, Shleifer (1986) analyzes a model in which technological improvements arrive at a constant rate but in some equilibria are only implemented cyclically. The inventor of a new technology can earn temporary excess profit from its implementation but the entry of imitators eventually eliminates excess profits. For this reason, owners of new technologies would like to receive their profits when they are the highest, i.e., when aggregate activity is at its peak. Expectations about the arrival of booms therefore help determine whether firms are willing to postpone innovation until the arrival of a boom. If all potential innovators expect a boom only in the distant future, they may choose to delay implementation until the expected date of the boom. The economy then stays in a slump until all inventors innovate simultaneously and fulfill their expectation of a boom.

3. General Attributes of Non Stationary Search Equilibria

Consider a market in which consumers are imperfectly informed about the prices firms charge and thus engage in costly search. Given a search technology Z and the information they have regarding the current and future distributions of prices they decide on the optimal search rule. This search rule can determine the type or intensity of search they adopt at each period and the optimal stopping rule. In equilibrium the distribution of prices at every period is a result of profit maximization by firms given the consumers' search rule.

The search technology, Z, can, for example, be sequential, in which case only one price quotation can be bought at each period (e.g. McCall (1970)), noisy, (Burdett and Judd (1983)) in which case there is an exogenously given probability that a sample contains more than one price quotation, or a combination of FSS and sequential search such that consumers decide at each period on the number of price quotations they would like to buy (Morgan and Manning (1982, 1985)).

The standard approach of equilibrium search theory (e.g. MacMinn (1980), Reinganum (1979), Rob (1985), Burdett and Judd (1983)) is to derive a stationary (possibly degenerate) price or wage distribution which represents an optimal response by sellers (employers) and is consistent with the optimal search of buyers (workers), given the search technology. In general, however, there is no reason to believe that sellers are committed to prices they have posted in the past. Firms can change prices over time which, in principle, may lead to nonstationary price distributions. Once the assumption of stationarity is dropped, the consumers' decision problem is much more complex because the optimal search rule now accounts for future changes in the distribution of prices.

For example, consider the case in which risk neutral consumers search sequentially, sampling a single price at each period. At period t, they anticipate that the average market price at t+1 is Ep_{t+1}. This information helps determine their reservation price at t. Specifically, they will reject a price exceeding:

$$(Ep_{t+1} + c)(1 + r)$$

where $r \geq 0$ is the rate of time preference and $c > 0$ is the cost of observing a price. If the price distribution is stationary, Ep_t is constant so that the reservation price is constant as well. In a nonstatationary environment, however, consumers need to consider not just period $t+1$ but also the price distribution at all future periods. Thus the reservation price at period t, denoted $\tilde{p}_t$, satisfies the following condition:

$$(1) \qquad \tilde{p}_t \leq \min_{\tau > t}(Ep_\tau + c)(1 + r)^{\tau - t}.$$

If this condition does not hold there is a period τ such that instead of paying $\tilde{p}_t$ at period t the consumer, will, on the average, be better off by deferring search until period τ.

When the search technology allows consumers determine the number of price quotations they purchase every period, their reaction to a nonstationary price distribution can be even more complex. Specifically, they might wish to intensify their search in particular periods when future price distributions are likely to be less favorable. In this case, firms must account for the changes in consumers' reservation prices and search intensities along time when determining prices at each period..

We now provide two examples of cyclical search equilibria. The first is a simple example in which the cycles are a result of nonstationary consumers' expectations. In the second example we will analyze a job market in which cycles are determined endogenously as a result of the dynamic interaction between workers and firms.

4. An Example of a Simple Cyclic Search Equilibrium

A cyclic search equilibrium can be obtained very easily in the sequential search setting. Consider, for example, the problem examined by Diamond (1971). He showed that if all consumers have a positive search cost, and the search technology is sequential, the only equilibrium is that in which all firms charge the monopoly price. By allowing for nonstationarity, however, we can easily construct cyclic equilibria in a dynamic setting.

Consider a market consisting of a continuum of identical, infinitely lived risk neutral consumers and a continuum of infinitely lived, identical, profit maximizing firms.

At each period a new cohort of consumers enters the market, each of whom wishes to buy exactly one unit at a price not exceeding p^*. In each period, a consumer in the market may solicit at most one price from a randomly selected firm at a cost of $c > 0$. Upon purchasing his unit, he leaves the market forever. Consumers minimize the expected cost of purchasing a unit, including the price paid and search costs (for simplicity, ignore discounting). We claim that the following dynamic price path is an equilibrium:

At each even period t all firms charge the monopolistic price p^* and at every odd period, all firms charge $\hat{p} > p^*$. Consumers adopt the following search rule. They search only in even periods in which their reservation price is p^*. At odd periods they are out of the market. Thus consumers entering at even periods solicit a price and buy immediately. Consumers entering at odd periods only solicit a price in the following period, at which time they buy at p^*.

The above is an equilibrium as no firm or consumer can benefit by changing its behavior. The proof of this claim is based on our assumption of an infinite number of firms and agents; As no firm can on its own cause a change in the price distribution, it cannot induce consumers to search at odd periods. Thus lowering the price at that period will not increase profits.

The preceding equilibrium is cyclic and exhibits nonstationary patterns both in prices and in the quantity sold. It is clear from our construction that we can construct other cycles in a similar fashion.

This type of cyclic equilibrium is similar to the type of cycles described in section 2. If all consumers expect that at odd periods all firms charge $\hat{p}$, then it is indeed equilibrium behavior on the part of firms to charge this price. Moreover, non cyclical equilibria exist as well. If all consumers expect p^* at each period, this stationary price path is an equilibrium. Thus the driving force behind these cyclic equilibria is the essentially arbitrary expectations of consumers. This is, however, not the only way to achieve cycles in a search equilibrium. Our objective in the next section is to illustrate cyclic equilibria in which the price distribution at two consecutive periods **cannot** be identical, i.e. given an equilibrium price distribution at period t, this price distribution is never an equilibrium at period $t-1$. Thus in this case, non-stationarity is an inherent feature of the model and not just an outcome of choosing expectations in a particular way.

5 A Model of Cyclical Job Search

In this section we present a simple model of job search which is based on our previous paper (Fershtman and Fishman (1989)).

In each period a new cohort of identical, infinitely lived workers enters the labor market. The reservation wage of each worker is w^* such that no one accepts a job that pays less than w^*. There is an infinite number of firms who all have the same technology. By employing a worker worker for one period, λ units of a product x are produced which can be sold at a price P_x. Thus the per period profits of the firm from hiring a worker at a salary w is $\pi(w) = \lambda P_x - w$.

Firms may offer different wages and we assume that workers are imperfectly informed. They know the distribution of wages but do not know the wage offered by each firm. Once a worker accepts a job offer with a wage of w he continues to receive this wage throughout his life. Thus, we exclude on-the-job search and moreover do not allow the worker to resign his job and search for another job. Letting $r > 0$ be the common discount factor, the worker's life time income is $I(w) = w/r(1 + r)^t$ where t is the period in which the worker accepts the employment.

We assume that workers wish to maximize their discounted lifetime income such that they are indifferent between accepting an offer of δw today and an offer of w in the next period when $\delta = \frac{1}{1+r}$.

We let $a > 0$ denote the measure of new workers per firm entering the market at every period. Since workers do not necessarily accept an offer in their first period in the market, the unemployed might accumulate. Thus, let $a_t \geq a$ be the measure of workers per firm at period t. Since all workers are identical, there is no difference between a worker who just entered the market and one who entered several periods ago.

Let $G_t(w)$ be the, possibly degenerate, distribution of wages at period t. Workers know this sequence of distributions and search over time so as to find the wage that maximizes their discounted lifetime income.

We assume that the search technology is a combination of FSS and sequential technologies. The model is essentially a dynamic extension of the model studied by Burdett and Judd (1983). At every period each worker may solicit any number of job offers at a constant cost of $c > 0$ per offer. All the job offers demanded at period t are received simultaneously. Workers observe these job offers and then decide whether to accept one of them or to continue to search at the next period.

Firms are not committed to any job offer for more than one period. In particular we allow firms to change the wage they offer every period.

For convenience of the exposition, we will assume there is a terminal period $T > 1$ at which employment may be accepted (but jobs accepted prior to or at T pay w forever). Our analysis obtains without change for an infinite horizon as well, however.

We let q_t^n be the probability that a randomly selected worker observes n wage quotations at period t. The workers' behavior at period t is thus summarized by

$$(< q_t^n >_{n=0}^{\infty}, \bar{w}_t^n)$$

where $\bar{w}_t^n$ is the reservation price of a worker who observes n wage offers at period t.

Note especially, that we do not exclude the possibility that $n = 0$. That is to say, workers may decide not to search at all at any period. Clearly, when the wage distribution is stationary such behavior cannot occur in equilibrium as workers are impatient. When the wage distribution is non stationary, however, one can imagine a situation in which workers defer costly search in anticipation of more favorable wage offers in future periods.

We define equilibrium as the following tuple:

$$\langle a_t, \langle q_t^n \rangle_{n=0}^{\infty}, \tilde{w}_t, G_t(w) \rangle_{t=1}^{T}.$$

such that:

(i) At every period t, given $(a_t, \langle q_t^n \rangle_{n=0}^{\infty}, \tilde{w}_t)$ each firm maximizes its profits by offering a wage in the support of $G_t(w)$. Moreover every wage in the support of $G_t(w)$ yields the same payoff and firms cannot gain by deviating and offering a wage outside of the support of $G_t(w)$.

(ii) For every t, given the sequence of distributions, $G_t(w)$, $G_{t+1}(w), \ldots, (\langle q^n \rangle_{n=0}^{\infty} \tilde{w}_t)$ is consistent with optimal search behavior of workers.

A **non-stationary dynamic search equilibrium** is an equilibrium that has the property: $G_{t_1}(w) \neq G_{t_2}(w)$ for some t_1, $t_2 \leq T$.

A **cyclical** dynamic search equilibrium is a non-stationary equilibrium for which $G_t(w) = G_{t+z}(w)$ for some given integer z.

Note that the above definitions are given in terms of the wage distributions. One can, however, also think in terms of employment cycles. In the analysis that follows we show how the two types of non-stationarities are related.

We analyze the model by backward induction, i.e. analyzing the terminal period T and then continuing backwards. The analysis of the last period is identical to the analysis of single period non-sequential search which was solved by Burdett and Judd (1983).[1] They showed that there are 1, 2, or 3 market equilibria; one monopoly wage equilibrium and zero, one or two dispersed wage equilibria. In any dispersed price equilibrium, a proportion $1 > q > 0$ of buyers observe only one price while the proportion $1-q$ observe two prices.

Since firms are indifferent between offering w^* or any other wage in the support of $G_T(w)$, the equal profit condition is:

$$(2) \qquad (P_x\lambda - w^*)q = (P_x\lambda - w)[q + 2(1-q)G_T(w)].$$

Therefore

$$(3) \qquad G_T(w) = \begin{cases} 0 & \text{if } w \le w \\ \dfrac{q(w - w^*)}{(P_x\lambda - w)2(1-q)} & \text{if } w^* < w < \bar{w} \\ 1 & \text{if } w \ge \bar{w} \end{cases}$$

where

$$(4) \qquad \bar{w} = \frac{qw^* + P_x\lambda\, 2(1-q)}{2 - q}.$$

Let $v(w^*, q)$ be the expected difference between the income of a worker who searches once and a consumer who searches twice. At the last

[1]The following formulae differ slightly from those of Burdett and Judd since they study price, rather than wage dispersion.

period, workers simply wish to maximize their wage. Thus:

$$(5) \qquad V(w^*, q) = 2\int_{w^*}^{\bar{w}} wG_T(w)dG_T(w) - \int_{w^*}^{\bar{w}} wdG_T(w).$$

In equilibrium, workers are indifferent between sampling once and sampling twice. Thus at equilibrium

$$(6) \quad V(w^*,q) = c.$$

Substituting (3) in (5), integrating by parts and solving the integrals gives:

$$(7) \quad V(q, w^*) = \gamma\cdot\{w^* - \bar{w} + (\ln(r - \bar{w} - \ln(r - w^*)(w^* - r + 2\gamma r - 2\gamma w^*)$$

$$+ \frac{\gamma}{r-\bar{w}}(\bar{w}^2 + 2w^* r + w^{2*}) - \frac{2\gamma w^* r}{r - w^*} + 2\gamma w^* - 2\gamma\bar{w}\}$$

where $\gamma = \frac{q}{2(1-q)}$.

Numerical analysis reveals that $V(q,w^*)$ is a bell shaped function of q, attaining a unique maximum at some q^*, $0 < q^* < 1$, and that $V(q,w^*) \to 0$ as $q \to 1$ and as $q \to 0$. Thus there exists $c^* > 0$ such that:

1) If $c < c^*$, there exist two wage dispersion equilibria corresponding to the two values of q for which $V(q,w^*) = c$.

2) If $c = c^*$, $G^*_T(w)$ is uniquely determined.

3) If $c > c^*$, no wage dispersion equilibrium exists. In this case the unique equilibrium is the single wage (Diamond) equilibrium, w^*.

It can also be shown that $V(q,w^*)$ is shifted down by an increase in w^*. This important property of $V(q,w^*)$ will be subsequently exploited to derive the cyclical equilibrium.

Let E_T denote the mean of G_T. If $c < c^*$, there will exist two values of E_T, one corresponding to each equilibrium value of q. Our analysis will not be based on a specific choice between these two equilibria.

Now consider a worker in the market at $T-1$. As discussed in section 3, his reservation wage is not exogenous but must account for the possibility of further search in the last period. Specifically, his expected payoff from searching again in the following period is $\delta\left\{\frac{E_T}{r} - c\right\}$. Thus a wage w is accepted at $T-1$ if and only if $\frac{w}{r} \geq \delta\left\{\frac{E_T}{r} - c\right\}$, i.e., iff $w \geq \delta\left\{E_T - cr\right\}$. This yields the reservation wage at period $T-1$:

$$\text{(8)} \qquad \tilde{w}_{T-1} = \max\left\{w^*, \delta(E_T - cr)\right\}.$$

There are three possibilities: First, if $\delta(E_T - cr) \leq w^*$, $\bar{w}_{T-1} = w^*$. In this case, wages are distributed identically at T-1 and T. In fact, in this case prices are distributed identically at each period and the equilibrium is stationary.

A second possibility is that $w^* < \delta(E_T - cr)$. In this case, $\bar{w}_{T-1} > w^*$ and $G_{T-1} \neq G_T$. G_{T-1} is non degenerate if there exists q_{T-1} such that $V(\bar{w}_{T-1}, q_{T-1}) \geq 0$. G_{T-1} is constructed analogously to G_T by substituting $\bar{w}_{T-1}$ for w^*. It is obvious that in this case the expected wage at T-1, $E_{T-1} > E_T$; wages decline from T-1 to T. However, it is also possible that G_{T-1} is degenerate although G^* is not.

To see why, recall that an increase in the reservation price shifts the function $V(w,q)$ down. Thus it is possible that there exist q_T such that $V(w^*, q_T) \geq c$ but $V(\bar{w}_{T-1}, q) < c$ for all $q \in [0,1]$. When this is the case, what is the equilibrium wage configuration at T-1? Clearly each employer offers $\bar{w}_{T-1}$. None will offer more than this because every worker receiving this offer accepts it. It would then seem that all workers in the labor market at T-1 accept work at the wage $\bar{w}_{T-1}$. This is not the case, however. It is true that a worker who receives an offer of $\bar{w}_{T-1}$ accepts it. However, he can increase his expected payoff by not looking for work at T-1. The expected return from soliciting a wage at T-1 is $\frac{\bar{w}_{T-1}}{r} - c$. The expected return of a worker who is "voluntarily unemployed" at T-1 and seeks employment at T is $\frac{\tilde{w}_{T-1}}{r}$. Thus all workers in the market at T-1 remain unemployed and only accept a job in the following period; there is unemployment at T-1 and a "boom" in hiring and production at T.

To summarize, if there is wage dispersion at T the following possibilities exist at T-1:

(1) Wages are identically distributed at T-1 and T and there is full employment at each period.

(2) Wages are distributed differently at T-1 and T, the mean wage is greater at T-1 and there is full employment at each period.

(3) At T-1 all employers offer the same wage, all unemployed workers in the market at T-1 remain unemployed and there is a boom in hiring and production at T.

It is clear that the different wage and employment patterns described above are not confined to the last two periods but will in general occur throughout the market's horizon. This suggests the existence of cyclic equilibria. Such an equilibrium is presented in Table 1.

TABLE 1: SIMULATION OF CYCLES IN THE LABOR MARKET

$w^* = 0 \quad c = 5 \quad r = .2$

t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Ew	1.98	.40	.48	.58	.70	.83	2.0	.46	.55	.66	.79	1.95	.41	.49	.59	.70	1.85
$\bar{w}$	7.94	.4	.48	.58	.70	.83	7.86	.46	.55	.66	.79	8.07	.41	.49	.59	.70	8.5
$\tilde{w}$	.33	.4	.48	.58	.70	.83	.38	.46	.55	.66	.79	.34	.41	.49	.59	.70	0
U	0	a	$2a$	$3a$	$4a$	$5a$	0	a	$2a$	$3a$	$4a$	0	a	$2a$	$3a$	$4a$	0

Notes

Ew - Average Wage

$\bar{w}$ - Maximum wage offered in the market

$\tilde{w}$ - Reservation wage

U - Unemployment.

The patterns of equilibrium wages and unemployment specified in Table 1 are illustrated in figures 1 and 2.

Hiring occurs only at periods 1, 7, 12 and 17. These are the cyclic boom periods at which all unemployed workers in the market seek and accept jobs. During boom periods, wages are dispersed across employers. Boom periods are separated by spells of unemployment which endure for 5 periods. At each of these periods, unemployed workers in the market do not engage in costly job search and hence remain unemployed. All employers offer the same wage which is the reservation price of a worker whose search cost is sunk. That is, if an unemployed worker were to seek employment, she would be guaranteed to find an acceptable wage. In equilibrium, however, the time pattern of wages is such that it is unprofitable for her to invest in job search at any time other than a boom. It is especially interesting that the lowest wages are charged at boom periods, during which the reservation wage is at a minimum. This is because the average wage is at its peak; workers invest in search costs in anticipation of a high wage but are willing to settle for a very low wage once this cost has been sunk.

In fact, it is precisely because the reservation wage is "too high" during the unemployment spell that wage dispersion is absent; when $\tilde{w}$ is too high, the peak of the V( ) function lies below c. The level of the reservation wage is determined by the proximity to the next boom period. Thus $\tilde{w}$ is at its peak one period preceding the boom and at its minimum during the boom period, at which time the arrival of the next boom is furthest away. The interval between booms (the duration of the unemployment spell) is determined so that the reservation wage at the boom periods is small enough to support dispersion and, as a consequence, a high average wage.

It should be clear from the preceding discussion that the existence of the cyclic equilibrium is not limited to a finite horizon but may continue to cycle for ever. The cyclic pattern is not a consequence of an arbitrary, self fulfilling expectation but is deermined solely by the parameters of the model: the discount rate, the search cost, the reservation wage w^* and the technology.

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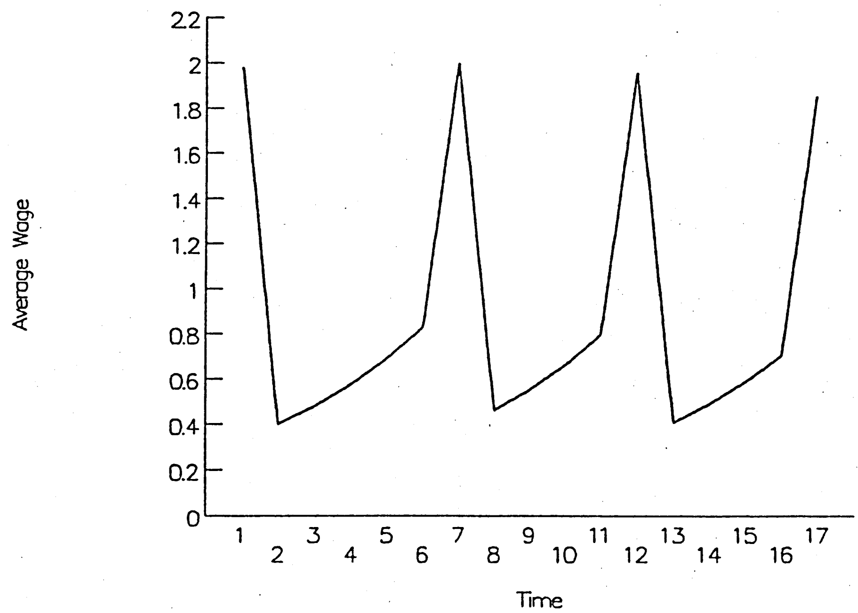
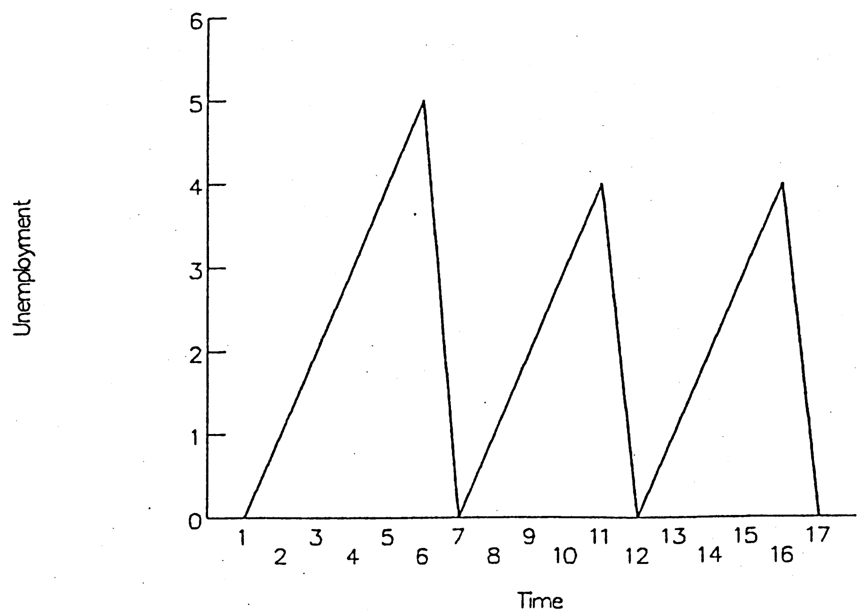
Equilibrium Wage Cycles



Unemployment Cycles



Equilibrium Wage Range