LABOR-MARKET DYNAMICS

by

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This paper presents a system dynamics model of worker mobility and wage determination in a multi-sector economy. The paper reviews the background and structure of the model, illustrates the model validation process, and sheds light on the dynamics of the labor market.

The labor-market model described in this paper has two purposes: to increase understanding of labor-market dynamics, and to analyze labor-market policies. The model provides structural explanations for numerous features of the labor market, such as the phase relation between wages and employment. Among other features, the model also explains the correlation between job openings and unemployment, and between wage changes and unemployment. Moreover, the model displays its potential for evaluating labor-market policies, such as increased intersectoral worker mobility.

The model's response to experimental step and fluctuating changes in desired employment provides a basis for explaining characteristic features of the labor market. For additional validation, the model's response to inputs derived from US data over the period 1954-1973 has been examined. The degree to which the labor-market model replicates US labor-market behavior over that period furthers confidence in the model.

The ultimate purpose of the model is to analyze policies when embedded in a larger model of national socio-economic behavior. (The Systems Dynamics National Model is being developed in the Alfred P. Sloan School of Management, MIT.) Although well beyond the scope of this paper, the labor-market model will be used to evaluate such policies as increasing the efficiency of matching workers to job openings and reducing employee turnover. The labor-market model will also play a vital role in the search for greater understanding of--and for policies that affect--the apparent Phillips curve tradeoff between inflation and unemployment.

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I. INTRODUCTION

This paper summarizes the development and testing of a system dynamics model of worker mobility and wage determination in a multi-sector economy.[1] The purpose of the paper is to highlight the model structure, to illustrate the range of validation tests performed on the model, and to increase understanding of labor-market dynamics.

The procedure in this paper will be to first discuss the background of the labor-market model, next overview the model structure, and then illustrate the behavior of the model. Knowledge of the model structure will enable explanations for certain characteristic features of the real-world labor market. For example, the model structure helps explain the correlations between job vacancies and unemployment (the Beveridge curve), and between wage changes and unemployment (the Phillips curve).

Useful evaluation of a model is impossible without knowledge of the model's purpose. The labor-market model comprises one sector, called the labor sector, of a larger model of national socio-economic behavior.[2] The terms "labor-market model" and "labor sector of the National Model" refer interchangeably to the structure described in this paper. The purpose of the labor-market model is twofold: first to increase understanding of labor-market dynamics, and second,

[1] This paper reports some of the results of the author's Ph.D. dissertation (Runge 1976a), and expands on the material presented in Runge (1976b). The dissertation research was carried out under several grants, including those from the Rockefeller Brothers Fund and the National Science Foundation.

[2] The larger model, the System Dynamics National Model, is being developed by the System Dynamics Group, Alfred P. Sloan School of Management, MIT. For a description of the scope and purpose of the National Model, see Forrester, Mass, and Ryan (1976).

in conjunction with the larger National Model, to analyze labor-market policies.

The System Dynamics National Model incorporates the major features of national socio-economic behavior as endogenous variables. The interaction of these variables will generate the economic growth, instability, and inflation that characterize the United States economy. The National Model will address short-range and medium-range issues, such as the causes of business-cycle (3-7 year period), Kuznets-cycle (15-20 year period), and Kondratieff-cycle (45-60 year period) fluctuations, and long-term issues such as the one-time transition from growth to equilibrium. The National Model consists of six distinct model sectors: the production, labor, demographic, household, financial, and government sectors. The labor sector--the "labor-market model" discussed in this paper--receives inputs from other sectors on the demand for workers, worker income and assets, transfer payments, and the size of the workforce.

The labor sector supplies workers to the production sector of the National Model. The production sector, in turn, contains a standard set of equations, which are replicated for different sectors of the economy, such as capital goods or services. For each replication of the standard production sector, the labor sector determines worker hiring and quits, which along with layoffs comprise the flow of workers between employment and unemployment. In addition, the labor sector captures worker mobility between sectors. Wages are also generated in the labor sector for workers in each replication of the standard production sector

A major short-term issue treated in the National Model will be the apparent tradeoff between inflation and unemployment. When coupled with the other sectors of the National Model, the labor sector will exhibit short-term variations in unemployment and wage changes. The availability and willingness to work of

unemployed workers in the labor sector will significantly influence both the short-term inflation/unemployment tradeoff and the effectiveness of policies aimed at altering the tradeoff. The wage-change equation in the labor sector does not assume a tradeoff between unemployment and wage changes; rather, it seeks to incorporate the actual pressures that bear on wage-setting processes in the real world, such as the difficulty employers have in filling job vacancies.

Among the long-term issues treated by the National Model is the industrialization process, and constraints arising from shortages of capital, technology, and labor. When embedded in the National Model, the labor sector will display long-term changes in employment patterns among sectors of the economy. The labor sector will also demonstrate the effect of the availability of workers on such long-term changes. Any restriction in the flow of workers among sectors would constrain the growth of sectors attempting to expand. Moreover, higher wages needed to attract workers to growing sectors can contribute to inflation.

The development of the labor-market model draws on a wide range of descriptive, theoretical, and empirical material. For example, the wage-change formulation relies on descriptive analyses of the pressures affecting wage changes, as well as on the sizeable body of empirical literature aimed at explaining statistically the rate of change of wages. The specification of worker movements between employment and unemployment incorporates insights gleaned from theoretical and empirical studies of turnover in the labor market. The formulations for intersectoral worker mobility borrow from the understanding of the determinants of worker movements gained from numerous empirical studies.

Conceptually, the labor-market model has most in common with the job search-turnover theory of the labor market.[3] The model incorporates stocks of employed and unemployed workers, as well as the network of feedback relations that govern the flows between worker stocks. According to Holt (1974, p. 1), the job search-turnover theory of the labor market

> ...visualizes a complex set of dynamically interacting labor markets which are characterized by great heterogeneity of jobs and workers, massive turnover flows in and out of the labor force and between jobs, and limited information which leads to substantial investments in search. The aspirations of workers for income and satisfaction interact with those of employers for high output and low labor costs. Human capital is accumulated by a worker through his sequence of job experiences, both within and between firms. Wages and working conditions are bargained for by workers individually and collectively through unions. The movements of workers between jobs often are impeded by barriers related to race, sex, age, and class, as well as by geography and occupation.

Figure 1 shows a simplified diagram of important labor-market stocks and the flows affecting them. Manpower requirements are derived from the demand for goods and services, shown at the bottom of Figure 1. A higher demand for production increases the manpower required, leading to the creation of job vacancies and a reduction of layoffs. The creation of new vacancies causes the stock of job vacancies to increase; reduced layoffs tend to increase the stock of employed workers and to decrease the stock of unemployed workers. The increased number of job vacancies induces more hires and recalls, which further augment the stock of employed workers and diminish the stock of unemployed workers. On the other hand, greater job opportunities signaled by more job vacancies promote increased quits, which tend to reduce the stock of employed

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[3] For theoretical development of the job search-turnover theory, see Holt and David (1966), and Holt (1970).

workers and to increase the stock of unemployed workers. As the stock of employed workers rises, the manpower available for production increases, thereby diminishing subsequent creation of job vacancies. Furthermore, conditions within the labor market affect retirements and the flow between the stock of family members not in the labor force and the stock of unemployed workers.

The heavy dashed line in Figure 1 shows the boundary of the labor market for the purposes of this study; the labor-market model does not embody the creation of job vacancies nor flows into and out of the labor force. (In the National Model, flows into and out of the labor force are determined in the household sector, and the creation of job vacancies takes place in the production sector.)

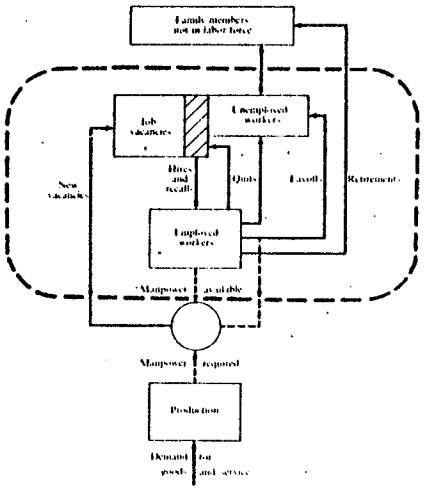

Figure 1. Labor-market stocks and flows
Source: Holt (1970, p. 57, Figure 1 adapted.)

While drawing heavily on prior work, the labor-market model has important distinctive features. First, the model has a comprehensive perspective on the operation of the labor market. With the exception of the job search-turnover theory mentioned previously, analyses of labor-market dynamics usually focus on the determinants of only a single rate of flow, such as the study of quits in Severn (1968), or of wages in Behman (1964). Such a fragemented approach limits the usefulness of those studies for refining labor-market policy or theory. The embodiment of wage determination, together with worker stocks and intra-sectoral and intersectoral worker flows, is a unique feature of the labor-market model.[4] In developing a comprehensive representation of the labor market, the model interrelates the causes as well as the consequences of worker movements.[5]

As a second distinctive feature, the determinants of model flows are not limited solely to factors for which quantitative information exists. The model formulations aim to capture the same influences on decision-making that govern real-world worker mobility and wages, whether or not data on those influences has been or can be compiled. For example, the influence of the supply-demand balance for workers on wage changes is commonly expressed in empirical studies through the level of unemployment (for which data exist). In contrast, the labor market model incorporates the pressure on wage changes arising directly from the length of time employers require to fill job vanacies, even though data generally do not exist on the duration of job vacancies.

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[4] See Holt (1974) for the outline of an approach to modeling the labor market with a comparable degree of comprehensiveness.

[5] Laird (1974) stresses the importance of incorporating feedback into models of worker movements.

II. STRUCTURE OF THE LABOR-MARKET MODEL

The labor-market model supplies workers to the various production sectors in the National Model. While all workers could be drawn from a single nonemployed[6] pool, the model instead incorporates a separate nonemployed pool for each production sector. Such a structure reflects the limited worker availability that a given production sector may face at any time due to tradition, specialized training, or lack of information, regardless of the total number of nonemployed workers. To permit worker movements among sectors, the model utilizes a general nonemployed pool, into which workers flow from sector nonemployed pools, and from workers flow to sector nonemployed pools. In short, the structure exhibits a star-shaped network of labor flows, with the general nonemployed pool at the center and one sector nonemployed pool and one sector employed pool along each arm of the star.

Figure 2 illustrates a typical arm of the star-shaped network of labor-market flows. The general nonemployed pool connects with as many sector nonemployed pools as there are production sectors in a given version of the National Model. The flow of workers from the general nonemployed to the sector nonemployed pools is called arrivals in sector; the opposite flow is termed departures from sector. The hiring rate and the separation rate connect the sector nonemployed and the sector employed pools within each production sector.

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[6] Workers without jobs in the labor-market model include the passive as well as the active unemployed. The passive unemployed are the jobless who are not actively seeking work. To avoid confusion with the US Bureau of Labor Statistics "unemployed" concept, which includes only workers actively seeking jobs, the model uses the broader term "nonemployed."

The star-shaped structure in Figure 2 significantly reduces the complexity of the flows in the real-world labor market, where each pool of workers is potentially linked to all other pools. Nevertheless, Figure 2 represents the essentials of worker mobility. For example, even the direct flow from a job in one sector to a job in another sector is captured. The durations of stay in the nonemployed pools which intervene between any two employed pools are averages over a wide range of different individual durations of stay; the duration of stay for some workers is much shorter than average. Direct job-to-job movement corresponds to a flow through the intervening nonemployed pools with a very short duration of stay.

All production sectors are treated in a standard way in the labor-market model: the same mobility equations operate for each production sector, with parameter values set to represent the particular characteristics of each sector. In other words, the labor-market model captures <u>all</u> worker mobility in the four flow rate equations indicated in Figure 2. One additional rate in Figure 2 represents the change in wages in each sector. These five equations form the core of the labor-market model.

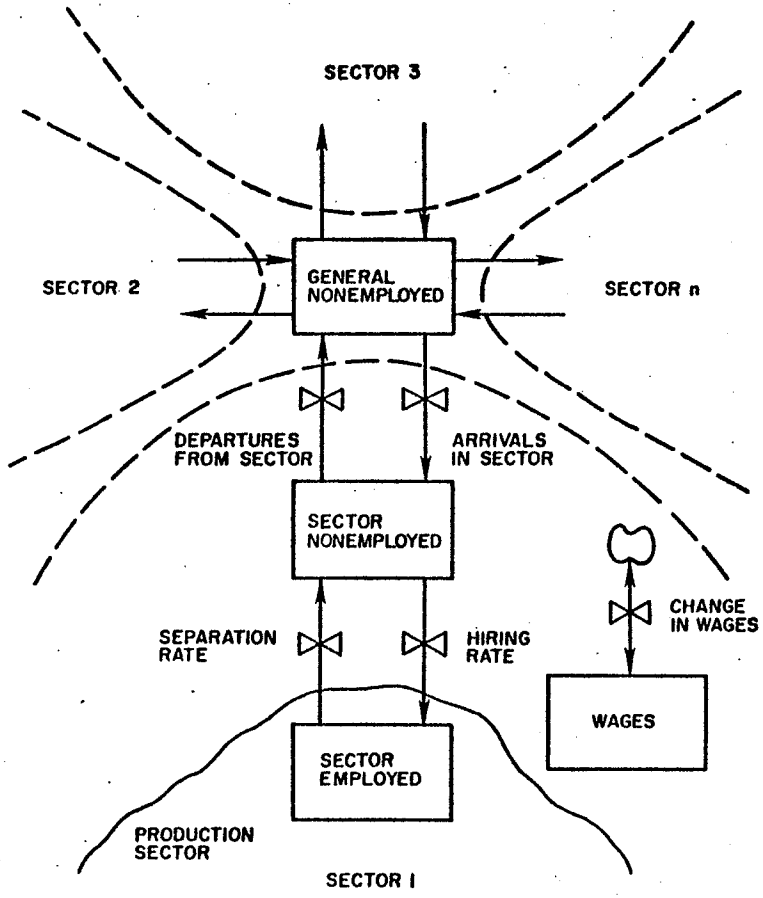

Figure 2. Basic structure of the labor-market model

A. Hiring Rate

Figure 3 shows the influences on the hiring rate. As depicted on the right side of Figure 3, an increase in the backlog for workers (analogous to job vacancies) raises the hiring rate. However, a higher backlog for workers also reduces the relative availability for hiring, defined as the ratio of the sector nonemployed to the backlog for workers. The probability that a given job opening is filled in a given time period decreases as the relative availability for hiring declines. Therefore, a higher backlog for workers decreases the probability of filling a given job opening in a given time period, thereby making any rise in the hiring rate less than proportional to the increase in backlog.

The disposable income of sector employed also influences the hiring rate. As disposable income of sector employed increases, the hiring rate also rises due to the greater attractiveness of holding a job in the sector. However, the net effect of disposable income of sector employed on the hiring rate depends on the length of week for labor. For a given income, a longer length of week for labor tends to depress the hiring rate. If the length of week for labor in a sector is too long, workers are discouraged from accepting work in the sector.

In Figure 3, the hiring rate is negatively affected by the well-being of the sector nonemployed. The well-being of the sector nonemployed increases as transfer payments to the sector nonemployed increase, duration of transfer payments lengthen, and assets per worker grow; well-being decreases as the duration of stay in the sector nonemployed pool (equal to sector nonemployed divided by hiring rate plus departures from sector) lengthens. An increase in the

well-being of sector nonemployed reduces the economic incentive to work and tends to depress the hiring rate, and vice versa.[7]

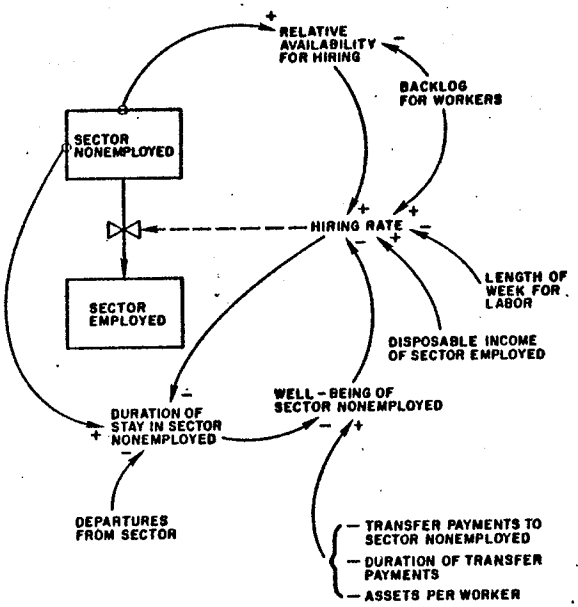

Figure 3. Influences on hiring rate.

B. Separation Rate

Figure 4 shows the influences on the separation rate. The separation rate is the sum of the quit rate and the layoff rate. The quit rate is basically

[7] The positive effect that a long duration of unemployment has on a worker's willingness to accept a job is a cornerstone of the job vacancy-turnover theory of the labor market. The effect of transfer payments on job-search activity are reported, for example, in Myers and Schultz (1951).

proportional to the number of sector employed workers, but is also influenced by the well-being of sector nonemployed, the disposable income of sector employed, and the length of week for labor. Whenever job openings increase, and the hiring rate consequently rises, the duration of stay in sector nonemployed decreases. As a result, the well-being of sector nonemployed increases due to the reduced need to consume assets while not employed. Higher well-being of sector nonemployed tends to increase the quit rate.[8] On the other hand, high disposable income of sector employed tends to diminish the quit rate by making present jobs more attractive.[9] The length of week for labor also affects the quit rate. If the length of week for labor exceeds its traditional length (at a given income) or becomes excessively fatiguing, the quit rate rises.

The layoff rate in Figure 4--determined in the production sector of the National Model--is governed by a comparison between the desired and the actual number of sector employed. An excess of desired over actual sector employed leads to fewer layoffs; conversely, if actual sector employed is greater than desired, a higher layoff rate results.

[8] The response of quits to increased demand and hiring is discussed in Behman (1964), pp. 261-262.

[9] Burton and Parker (1969) discuss empirical evidence for the negative influence

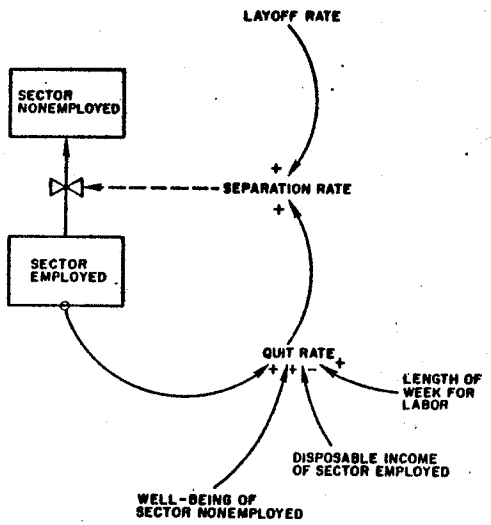

Figure 4. Influences on separation rate.

C. Arrivals in Sector

Figure 5 shows the influences on arrivals in sector. Arrivals in sector are proportional to the size of the workforce in the sector (the sum of sector employed and sector nonemployed). As discussed in Myers and Schultz (1951, pp. 70-71), a large portion of job information is transmitted by word-of-mouth; therefore, the larger the sector, the more nonemployed workers outside the sector are likely to hear of work there. Arrivals in sector are affected as well by the size of the general nonemployed pool; a smaller (larger) general nonemployed pool means a lower (higher) flow out of the pool. The duration of stay

in the general nonemployed pool (equal to a general nonemployed divided by total arrivals in sector) also influences arrivals in sector. A lengthening duration of stay in general nonemployed increases the financial hardship of remaining in the general nonemployed pool and raises the incentive to seek work. Therefore, in Figure 5, an increase in the duration of stay in general nonemployed raises the relative duration in general nonemployed, which then increases arrivals in sector. Transfer payments to the general nonemployed also influence arrivals in sector through their effect on the "acceptable" duration of stay in the general nonemployed pool. An increase in transfer payments to general nonemployed shortens the relative duration in general nonemployed, corresponding to greater economic well-being, which lessens the incentive to seek work and thereby depresses arrivals in sector.

Aside from the size of the workforce in a sector, the major sector-specific influences on arrivals in sector are the perceived income ratio and the relative perceived hiring delay. The perceived income ratio reflects the perception by workers in the general nonemployed pool of the income of workers in the sector relative to the average income of all workers in the economy. An increase in the income of workers in a sector tends to raise arrivals in sector because of the attractiveness of the greater earning potential there. The relative perceived hiring delay indicates the perception by workers in the general nonemployed pool of the hiring delay in the sector relative to the average hiring delay in the economy. The hiring delay measures the average time required to find work in a sector. A short hiring delay, signaling favorable demand conditions in a sector, increases arrivals in sector because the likelihood of finding work there is high.

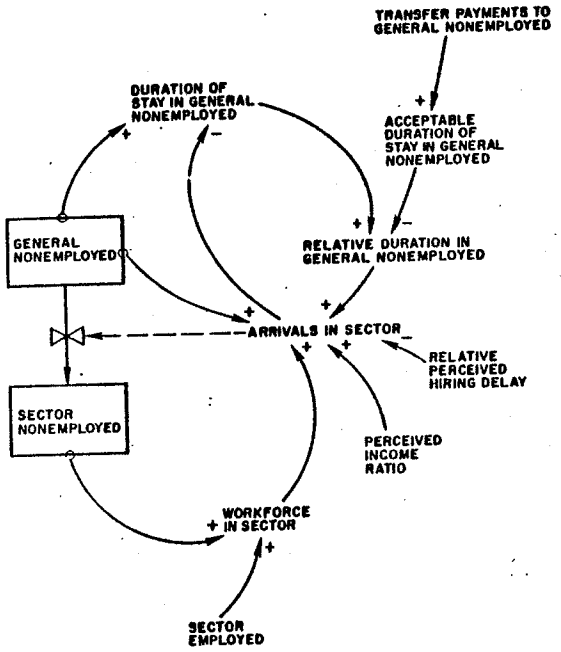

Figure 5. Influence on arrivals in sector.

D. Departures from Sector

Figure 6 shows the influence on departures from sector. Normally, some fraction of the sector nonemployed can be expected to depart to the general nonemployed pool for a variety of reasons, such as dissatisfaction or upward

mobility; therefore, departures from sector are proportional to the size of the sector nonemployed pool. Departures from sector are also influenced by the well-being of sector nonemployed: the higher the well-being of sector nonemployed, the less impetus for leaving the sector to seek work elsewhere. Departures from sector are also tempered by perceived average income, a measure of the perception by the sector nonemployed of the average income elsewhere in the economy. High average income elsewhere increases the attractiveness of leaving a sector.[10]

In Figure 6, the mobility of workers through the general nonemployed pool also influences departures from sector. A short relative duration in general nonemployed suggests high mobility, an encouragement for departures, and vice versa. The effect of the relative duration in general nonemployed on departure thus indirectly reflects the ease of finding work elsewhere.

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[10] A comparison of the sector-specific influences on arrivals in sector (Figure 5) and departures from sector (Figure 6) indicates that arrivals are responsive to such particular conditions in the sector as income and hiring delay. In contrast, departures are influenced only by the well-being of sector nonemployed. The concept of asymmetrical influences on arrivals and departures is consistent with the main thread of recent migration studies as discussed in Morrison and Relles (1975, pp. 1-4).

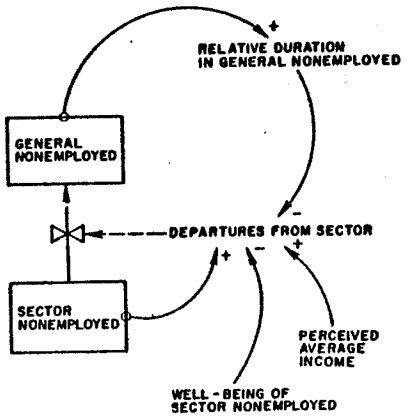


Figure 6. Influences on departures from sector.

E. Change in Wages

Figure 7 shows the influences on the change in wages in each sector. The change in wages is proportional to existing wages. In other words, the absolute change in wages due to a given percent change depends on the level of wages. The other influences on the changes in wages, when multiplied by the level of wages, determine the absolute change in wages.

Relative wages--wages in the sector relative to average wages in the economy--influence the change in wages. If average wages outside the sector increase, relative wages within the sector decline, creating upward pressure on the change in wages. The impact of relative wages on the change in wages

captures the effect of "secondary wage drift" discussed in Phelps Brown (1962). Secondary wage drift describes the influence that wage changes in one part of the economy have on wage changes elsewhere.

Perceived inflation in the nation also influences the change in wages. The perceived inflation in nation represents worker and employer perception of the rate of increase in prices.

Another influence on the change in wages is the delivery delay for workers. The delivery delay for workers, a measure of the average time needed to fill a job opening, provides the principal influence on the change in wages from the worker supply-demand balance in the model. A short delivery delay for workers reflects a slack labor market where job openings are easy to fill; a long delivery delay for workers, on the other hand, reflects tight labor-market conditions where job openings take a long time to fill. The use of delivery delay for workers as an influence on the change in wages in the labor-market model contrasts with the dominant practice in empirical economics. In a tradition established by Phillips (1958), model equations for the change in wages typically incorporate the unemployment rate as an indicator of the worker supply-demand balance. The unemployment rate is frequently used because data is lacking on other, more realistic indicators of the worker supply-demand balance. In the labor-market model, on the other hand, the delivery delay for workers indicates the relative difficulty employers have in filling job openings; the delivery delay for workers comes much closer to capturing real-world pressures on wage changes than the unemployment rate.

Figure 7 also shows an influence on the change in wages from the employment ratio in sector, which is the ratio of the actual to the desired number

of sector employed. When the desired exceeds the actual number of sector employed, upward pressure is placed on the change in wages, and vice versa.

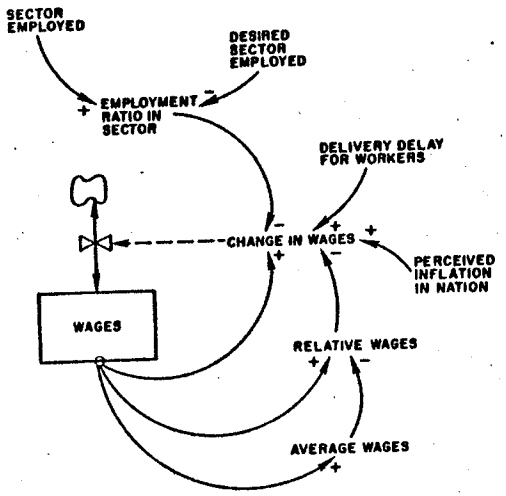


Figure 7. Influences on the change in wages.

III. BEHAVIOR OF THE LABOR-MARKET MODEL

The labor-market model, in both one- and two-sector versions, has been tested extensively for validation purposes. The model has been subjected to two classes of test inputs: simple (that is, step and fluctuating) inputs, and time-series inputs. Initial tests utilized a step increase in, and a fluctuating level of, desired employment. The initial test results showed a plausible model response to test inputs, and a relative insensitivity to sizeable parameter changes. The test results have permitted comparisons between the behavior of the model and the real-world labor market. Moreover, the model structure has provided explanatory insights into numerous features characterizing both the model and real-world labor markets.

The model has also been subjected to inputs derived from real-world data. A two-sector version of the model, representing the entire US labor market, proved capable of replicating real-world worker mobility and wages over the period 1954-1973, when driven by time series inputs.

Selected results of subjecting a one-sector version of the model to simulated business-cycle conditions will be reviewed below to illustrate the model testing process. The model was subjected to a $\pm$10% fluctuation in desired employment, with a period of 4 years, to approximate US business-cycle fluctuations in the demand for workers. The test provided a wealth of material for comparing model behavior to the real world. However, due to space limitations, only certain phase relations and correlations in the model will be treated here.

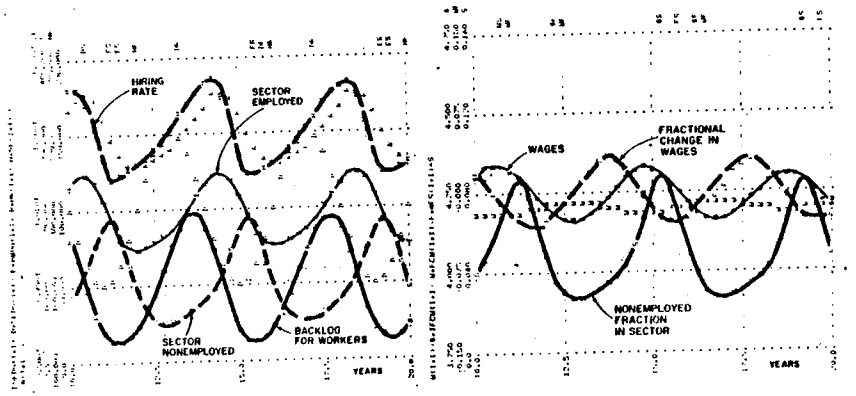
In Figure 8a, the hiring rate, the backlog for workers, and the levels of sector employed and sector nonemployed all fluctuate over amplitude ranges that agree with US business-cycle fluctuations.[11] The backlog for workers in Figure 8a leads the sector employed, peaking about 3/4 year before sector employed. A comparable phase relation exists between nonagricultural job openings and nonagricultural employment in the United States.[12]

Figure 8b shows the behavior of wages in the labor-market model. Wages fluctuate, in response to changing demand for and supply of workers, about an average value greater than their initial value. The tendency for wages to increase on the average arises from the greater flexibility of wages upward than downward. In the one-sector model used for Figures 8a and 8b, average wages in the economy are assumed to be constant; they therefore exert downward pressure whenever wages in the sector rise. Wages in Figure 8b fluctuate about a value where the downward pressure from the effect of relative wages offsets the greater upward flexibility of wages in the sector. If wages were increasing elsewhere in the model, the downward pressure on wages in the sector would diminish and wages would exhibit a secular rise in their average value. Such a tendency in the labor-market model--as in the real world--can be an important component of inflation. Wages in Figure 8b lag behind sector employed in Figure 8a by about 5 months. The lag of wages behind sector employed agrees with the real-world lag of wages behind employment in manufacturing, as noted in Gordon (1961, p. 289).

[11] The simulation shown in Figures 8a and 8b spans 20 years. The figures show only year 10 to year 20, however, to reveal more detail and facilitate examination of phase relations and correlations.

[12] See Moore and Shiskin (1967, p. 55).

Figures 8a and 8b show correlations between model variables that correspond to real-world correlations. For example, Figure 8a shows that the backlog for workers and the sector nonemployed are negatively correlated; an increase in the backlog for workers is accompanied by a decline in sector nonemployed, and vice versa. Figure 9a shows annual values of the backlog for workers and sector nonemployed from the simulation in Figure 8a plotted as percents of the workforce in the sector. On the vertical axis, the backlog fraction in sector is defined as the backlog for workers divided by the workforce in sector. The horizontal axis shows the nonemployed fraction in sector expressed in percent terms.



(a) (b)

Figure 8. Response of labor-market model to fluctuating desired employment.

Figure 9b shows real-world data comparable to that in Figure 9a.[13] In Figure 9b, the number of vacancies pending at the US Employment Service as a

[13] Figure 9b reproduces Figure 6 in Holt et al. (1971, p. 40).

percent of the labor force, called the vacancy rate, is plotted against unemployment as a percent of the labor force. A comparison of Figures 9a and 9b shows the qualitative agreement between the correlations in the two figures.[14] The structure of the labor-market model explains why such a correlation should exist in both the model and the real world. An increase in the backlog for workers, by increasing the hiring rate, tends to decrease the number of sector nonemployed, and vice versa, thereby inducing a negative correlation between backlog for workers and sector nonemployed.[15]

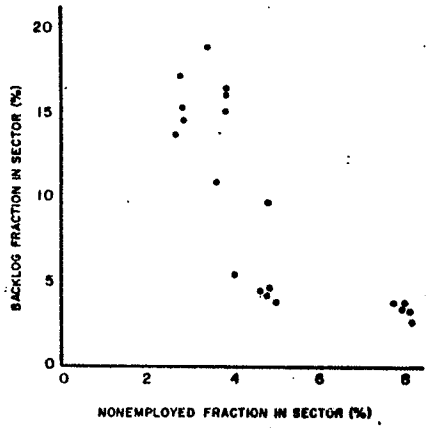


Figure 9a. Backlog fraction in sector versus nonemployed fraction in sector from simulation in Figure 8a.

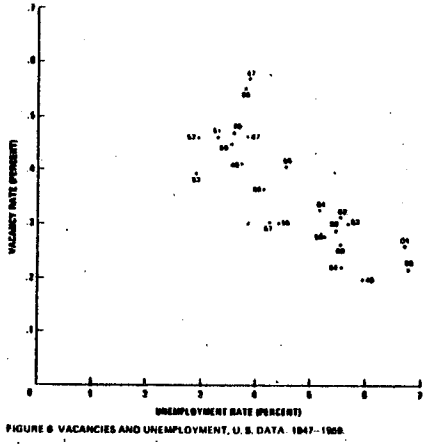


Figure 9b. Vacancy rate versus unemployment rate in United States.

[14] The vertical scales are different between Figures 9a and 9b because vacancy data used for Figure 9b understates the actual number of vacancies in the economy. Even if the data in Figure 9b did report all job vacancies, the scales would still differ because backlog for workers is a more inclusive measure of demand than officially defined job vacancies. (For example, "backlog for workers" includes demand for workers being recalled from layoff, but "job vacancies" does not.) The difference in vertical scale between two figures only alters the slope of the negative correlation; the underlying qualitative agreement between the two correlations is not affected.

[15] The model also displays a shift in the correlation between backlog for workers and sector nonemployed when transfer payments to the sector nonemployed increase. Gujarati (1972) found the same results in the real world.

Figure 8b reveals a second correlation of interest. The nonemployed fraction in sector and the fractional change in wages tend to be negatively correlated; an increase in the nonemployed fraction in sector is accompanied by a decline in the fractional change in wages, and vice versa. Figure 10a graphs data from the simulation shown in Figure 8b on the fractional change in wages versus the nonemployed fraction in sector, both expressed in percent terms. The curve through the data in Figure 10a expresses a regression of the fractional change in wages (FCW) on the reciprocal of the nonemployed fraction in sector (NFS), in an equation of the form FCW = A + B/NFS.

Figure 10b reproduces the original Phillips curve that relates the rate of change of money wages to the unemployment rate in the United Kingdom.[16] Comparison of Figures 10a and 10b reveals close agreement between the correlations in the two figures. Both show that the rate of wage change tends to accelerate as the unemployment rate declines. Conversely, as the unemployment rate increases, the rate of wage change falls with decreasing steepness. Moreover, the values of the fractional change in wages in Figure 10a agree well with those in Figure 10b for corresponding values of the nonemployed fraction in sector. The labor-market model structure explains the negative correlation between the fractional change in wages and the nonemployed fraction in sector: when the nonemployed fraction in sector declines, the increased competition for workers raises the difficulty of matching workers with jobs in a given time period, as manifested in a longer delivery delay for workers. The resulting upward pressure on wages from a longer delivery delay for workers induces a wage increase that correlates with the decline in the nonemployed fraction in sector.

[16] Figure 10b reproduces Figure 1 in Phillips (1958, p. 285).

The correspondence between model and real-world labor markets reveals the model's ability to capture labor-market dynamics realistically. Among other features, the model also shows a positive correlation between hiring and wage changes that agrees with the correlation shown in Behman (1964, p. 259). Moreover, the model structure explains the negative correlation commonly found between wage changes and the rate of change of unemployment[17] on the basis of stock-flow interactions in the labor market.[18]

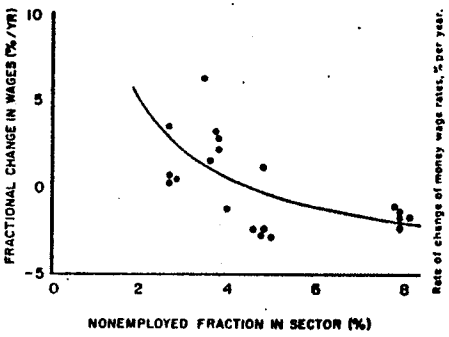


Figure 10a. Phillips curve derived from simulation in Figure 8b.

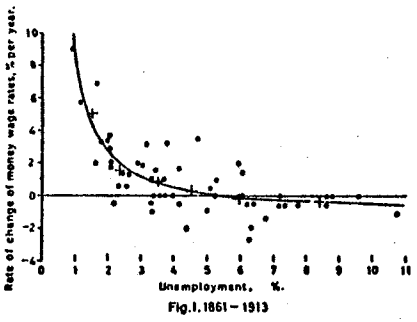


Figure 10b. Original Phillips curve relating the rate of change of money wages and employment.

[17] See Bowen and Berry (1963) for example.

[18] Space limitations preclude full discussion of such features here. See Runge (1976a, Chapter IV).

IV. S U M M A R Y

The labor-market model described in this paper draws on a wide range of descriptive, theoretical, and empirical literature. The model embodies a comprehensive theory of the causes and consequences of both intra- and intersectoral worker movements, and also encompasses the determinants of wage changes in the different sectors of a multi-sector economy.

The model tests to date have provided a solid initial basis for confidence in the model. The model's response to simple step and fluctuating inputs, as well as its performance when subjected to time-series inputs, yield many areas of congruence between the model and the real world. The model structure also sheds light on the dynamics of the real-world labor market.

When embedded within the larger National Model, the labor-market model ultimately will be instrumental in evaluating such manpower policies as increasing the efficiency of matching workers to job openings, and reducing employee turnover, for example. The labor-market model will also play a vital role in the search for greater understanding of--and for policies that affect--the apparent Phillips curve tradeoff between inflation and unemployment.

REFERENCES

Behman (1964) — Behman, S. "Labor Mobility, Increasing Labor Demand, and Money Wage-Rate Increases in United States Manufacturing," Review of Economic Studies, vol. 21, no. 4 (October 1964), pp. 253-266.

Bowen and Berry (1963) — Bowen, W., and R. Berry. "Unemployment Conditions and Movements of the Money Wage Level," Review of Economics and Statistics, vol. XLV (May 1963), pp. 163-172.

Burton and Parker (1969) — Burton, J.F., Jr., and J.E. Parker. "Interindustry Variations in Voluntary Labor Mobility," Industrial and Labor Relations Review, vol. 22, no. 2 (January 1969), pp. 199-216.

Forrester, Mass, and Ryan (1975) — Forrester, J.W., N.J. Mass, and C.J. Ryan. "The System Dynamics National Model: Understanding Socio-Economic Behavior and Policy Alternatives," System Dynamics Group Memorandum D-2248-2, Alfred P. Sloan School of Management (Cambridge: MIT, October 7, 1975).

Gordon (1961) — Gordon, R.A. Business Fluctuations (New York: Harper and Row, 1961).

Gujarati (1972) — Gujarati, D. "The Behavior of Unemployment and Unfilled Vacancies: Great Britain 1958-71," The Economic Journal, vol. 82 (March 1972), pp. 194-204.

Holt (1970) — Holt, C. "Job Search, Phillips Wage Relation, and Union Influence: Theory and Evidence," in Micro-Economic Foundations of Employment and Inflation Theory, by E. Phelps et al. (New York: W.W. Norton and Co., 1970).

Holt and David (1966) — Holt, C., and M. David. "The Concept of Job Vacancies in a Dynamic Theory of the Labor Market," in The Measurement and Interpretation of Job Vacancies, National Bureau of Economic Research (New York: Columbia University Press, 1966).

Holt et al. (1971) — Holt, C., C. MacRae, S. Schweitzer, and R. Smith. The Unemployment-Inflation Dilemma: A Manpower Solution (Washington: The Urban Institute, 1971).

Laird (1974) — Laird, M. "Dynamic Migration Models," in Readings in Urban Dynamics: Volume 1, edited by N.J. Mass (Cambridge: Wright-Allen Press, 1974).

Moore and Shiskin (1967) — Moore, G., and J. Shiskin. "Indicators of Business Expansions and Contractions," Occasional Paper #103 (New York: National Bureau of Economic Research, 1967).

Morrison and Relles (1975) — Morrison, P.A., and D.A. Relles. "Recent Research Insights into Local Migration Flows," Paper P-5379 (Santa Monica, Calif.: The Rand Corporation, February 1975).

Myers and Schultz (1951) — Myers, C., and G. Schultz. The Dynamics of a Labor Market (Englewood Cliffs, N.J.: Prentice-Hall, 1951).

Phelps Brown (1962) — Phelps Brown, E.H. "Wage Drift," Economica, vol. XXIX, no. 116 (November 1962), pp. 339-356.

Phillips (1958) — Phillips, A.W. "The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861-1957," Economica, no. 25 (November 1958), pp. 283-299.

Runge (1976a) — Runge, D. "Labor-Market Dynamics: An Analysis of Mobility and Wages," unpublished Ph.D. dissertation, Alfred P. Sloan School of Management (Cambridge: MIT, June 1976).

Runge (1976b) — Runge, D. "A Dynamic Model of Worker Mobility and Wage Determination: Structure and Behavior," Proceedings of the 1976 Summer Computer Simulation Conference (La Jolla, Calif.: Simulation Councils, Inc., PO Box 2228, 1976).

Severn (1968) — Severn, A. "Upward Labor Mobility: Opportunity or Incentive?" Quarterly Journal of Economics, vol. 82 (February 1968), pp. 143-151.