On the Cyclicality of Labor Market Mismatch and Aggregate Employment Flows

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Abstract

This paper combines a discrete-time dynamic general equilibrium articulation of the standard model of labor market search with observed U.S. time series measures on employment, vacancies, and aggregate output to uncover the cyclical properties of three unobserved forcing variables that comprise the exogenous state of the aggregate labor market: labor productivity, the rate of job separation, and the allocational efficiency of the labor market. We posit the latter variable to be inversely related to the degree of mismatch in the pool of searching workers and vacancies, given numbers of each, and identify its movements as scalar shifts in the standard matching function. Given that the model exactly reconciles observed net employment changes, our procedure also implies measured time series of the flows into and out of employment. We find that labor productivity, the job separation rate and allocational efficiency are all procyclical with the latter two highly variable. These cyclical patterns lead to procyclical implied gross employment flows, thereby concentrating labor force reallocation during booms. We discuss the implications for conventional views of business cycle fluctuations and for the standard search theories of labor market behavior.

Key words: Labor Market Search; Aggregate Employment Flows; Business Cycles

JEL classification: E24; E32; J40

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1 Introduction

Economists have long acknowledged that buyers and sellers of labor market services are challenged by search frictions to an extent not experienced by participants in other markets – frictions that originate in the wide cross-sectional variation in worker and job qualities, and the consequent burden placed upon labor market participants to process this information. With information frictions at the heart of labor market analysis, it is unfortunate that they are extraordinarily difficult, or even impossible, to observe in a systematic fashion. Attempts to understand measured labor market phenomena and their relation to business cycle fluctuations are doubtlessly frustrated by the limitation. This paper proposes an indirect measure of these hidden labor market qualities by combining information from the observable labor market aggregates with the information derived from a dynamic general equilibrium (DGE) articulation of the standard labor market search model.

We conceptualize these hidden qualities as an exogenous state vector, the key dimension of which gauges the degree to which the populations of searching workers and vacant positions are suited to each other. This then captures the efficiency with which labor markets allocate workers to jobs, and vice versa. Two additional dimensions, the average productivity of workers and the average rate at which workers separate from their current positions, complete the unobserved labor market state. Our procedure constructs a unique history of this unobserved state vector that simultaneously satisfies the restrictions imposed by DGE search and matching theory and the observed histories of aggregate output, employment, and vacancies. Given the history of the exogenous state vector, the internal logic of the search and matching model also implies realized time series observations on the gross flows of workers into and out of employment.

We intend this study to serve a dual purpose: one of measurement and the other of diagnosis. In the measurement domain, we gauge the cyclical characteristics of the unobserved exogenous variables and gross employment flows, measuring their variability and comovements. In doing so, we provide answers to a number of intriguing questions. Does the degree of labor market mismatch vary systematically over the business cycle, and if so, is it procyclical or countercyclical? Are the movements of workers into and out of employment procyclical, countercyclical or neither? Are the cyclical patterns of the employment inflows and outflows significantly different, i.e. are they asymmetric? The answers to these questions subsequently carry implications for the pattern of labor force reallocation over the business cycle, providing a basis for further theoretical speculation into the nature of business cycles. A strict Schumpeterian view of business cycle dynamics, for example, implies countercyclical labor force reallocation and a nearly teleological interpretation of recessions as periods 'creative' job destruction and factor reallocation. Our results will clearly inform such discussions.

In its simultaneous treatment of theory and measurement, the techniques that we apply in this paper not only allow us a glimpse of the unobserved, they also serve a diagnostic purpose designed to engender a deeper understanding of existing theory. By allocating all of the cyclical variation present in the observed endogenous variables to either theoretical variation, i.e. variation that is understood by a stable theoretical framework, or to exogenous variation in the unobserved forcing variables, the procedure separates cyclical phenomena that are understood through the lens of economic theory, from those that are not. From a pure measurement perspective, there is nothing further to be understood: the theory is perfect and so the exogeneity is well-defined and truly exogenous. Of course, we are not so sanguine. Some of the measured exogenous cyclical variation inevitably contains some part model misspecification. Indeed, we intend this paper to partly serve a 'pre-theoretical' function that informs future modeling efforts to enrich the current understanding of labor market dynamics and their linkages to aggregate economic fluctuations more generally. We expect such efforts to include theoretical structures that help explain the comovements between our exogenous variables.[1]

In recognition of the information problems on both sides of labor markets, Mortensen and Pissarides (1994) and Pissarides (2000) have provided researchers with an analytically convenient and intuitively pleasing framework to capture the costly search process induced by the informational complexity of labor markets – one which is readily amenable to macroeconomics analysis. Our theoretical identifying assumptions spring from a DGE implementation of their

[1] The literature reveals substantial interest in this endeavor. In addition to Merz (1995), Andalfatto (1996), Cole and Rogerson (1999), and Shimer (2005), a short list includes Lilien (1982), Abraham and Katz (1986), Blanchard and Diamond (1989), Blanchard and Diamond (1990), Caballero and Hammour (1994), Hall (1995, 2002, 2003), Den Haan, Ramey and Watson (2000), Gomes, Greenwood, and Rebelo (2001), Pries (2004).

framework, at the heart of which is a 'matching function' which determines the number of job matches formed in a given period – the gross employment inflow – as an increasing function of total job vacancies and the number of searching workers.[2] In its simplest form, the Mortensen-Pissarides framework determines the gross employment outflow as an exogenous constant fraction of total employment – the rate of job separation.

We adopt the Mortensen-Pissaides framework as our instrument of measure primarily for its ability to reconcile net employment changes with gross employment flows using well-articulated dynamic economic theory. By construction, the cyclical properties of the three exogenous forcing variables in our analysis – aggregate labor productivity, the rate of job separation, and allocational efficiency of labor markets – are mutually consistent with the this framework and the time series observations on employment, vacancies, and aggregate output. The aggregate labor productivity measure (Z) follows quickly from the model economy's resource constraint and possesses cyclical properties nearly identical to conventional labor productivity measures. In keeping with the most basic Mortensen-Pissarides model, the rate of job separation (σ) is exogenous and simply gives the fraction of employed persons that will separate from their jobs, for whatever reason, during a particular period and must be determined simultaneously with the exogenous allocational efficiency variable.

Our third characteristic of the hidden labor market state captures the efficiency with which existing labor market institutions pair searching workers with available jobs. This is not as transparent as the first two and merits further discussion. We take as axiomatic that the matching function, say $M(V,U)$ – where the flow into employment is a function of the number of vacancies and searching workers – owes its existence to the notion of mismatch, "an empirical concept that measures the degree of heterogeneity in the labor market across a number of dimensions, usually restricted to skills, industrial sector, and location" (Petrongolo and Pissarides, 2001). That is, in the absence of mismatch, jobs and workers would match instantly. Accordingly, an exogenous increase in labor market mismatch, given the matching inputs (V,U), decreases the number of matches formed, or equivalently, decreases the 'allocative efficiency'

[2] See Petrongolo and Pissarides (2001) for a comprehensive review of the literature regarding the matching function and its role in search and matching models and in empirical studies.

of the aggregate labor market. Since we are interested in exploring the cyclical properties of mismatch and allocational efficiency, we relax the structural stability of the standard matching function by allowing exogenous multiplicative shifts in the rate of match formation given the levels of matching inputs. Thus, we write $\chi M(V,U)$, where $\chi > 0$ measures the allocational efficiency of the labor markets.[3]

Given the three exogenous components of the hidden labor market state (Z, σ, and χ), we are able to derive measures of job finding and job separation. Job finding is mediated by the matching function and is given by the expression $\chi M(U,V)$; job separation is simply the product of the job separation rate and employment, or σN. To measure the exogenous shocks, we first derive the complete set of independent theoretical restrictions implied by the socially efficient allocation of the DGE search model. The model is essentially borrowed from Merz (1995) and Andalfatto (1996), but abstracts from physical capital accumulation.[4] This provides us with three conditions that characterize the equilibrium allocation of employment, vacancies, and output: 1) a resource constraint defining the feasible allocations, 2) an Euler equation implied by an intertemporally efficient program of vacancy-creation, and 3) the equation of motion for employment reconciling gross employment flows with net employment flows. To solve the model, we log-linearize these conditions and specify a general VAR(1) process to govern the joint shock process. With knowledge of the parameters defining the VAR(1) process, the entire system is easily inverted to obtain a history of exogenous shocks conditional on these parameters. We have no such prior knowledge, of course, and so we follow the simulated method of moments procedure proposed by Lee and Ingram (1991) to obtain these parameters.

The measurement function of our paper shares the aim of numerous predecessors that measure unobserved time series characteristics from existing evidence and theoretical restrictions, with the works of Solow (1956) and Prescott (1986) perhaps the most famous of these. In the

[3] In principle, χ would also pick up lower frequency instability in the matching function contributed by technological advances in matching, changes in government policy, and similar changes. By removing a low-frequency trend from all of the observed endogenous variables prior to analysis, we effectively filter out these movements in allocational efficiency, *a priori*.

[4] Unlike their models, ours abstracts from physical capital accumulation. This simplification not only allows us to economize on the number of parameters in the joint distribution of shocks that must be estimated, but also facilitates comparisons with studies of the aggregate labor market that rely more closely on the original Mortensen-Pissarides framework (e.g. Mortensen and Pissarides (1994), Cole and Rogerson (1999), and Shimer (2005a)).

context of DGE environments, this process is initially formalized by Ingram, Kocherlakota, and Savin (1994) who advocate the use of singular models to produce inferred shock series that are unique. This approach was subsequently extended by Chari, Kehoe, and McGratten (2003) who use maximum likelihood to estimate the parameters governing the distribution of shocks. They also emphasize the diagnostic role of the procedure. Our technique strongly resembles theirs, except for the method used to extract the parameters governing the exogenous forcing process; we use simulated method of moments rather than maximum likelihood.

In its specific attention paid to labor market dynamics, the measurement function shares the goal of more direct attempts to infer the aggregate cyclical characteristics of gross employment flows using partial evidence offered by inherently incomplete data sets. Blanchard and Diamond (1990) analyze the gross worker flow data from the Current Population Survey (CPS) compiled by the Bureau of Labor Statistics (BLS). Unfortunately, these observed worker flows do not reconcile period-to-period aggregate net employment changes and often display large discrepancies, even of opposite sign. Davis and Haltiwanger (1992) and Davis, Haltitwanger, and Schuh (1996) construct and analyze gross job flow data in U.S. manufacturing based on plant-level changes in employment. Given that manufacturing is a small and declining fraction of U.S. employment, drawing inferences regarding aggregate job and worker flows from their results is problematic. In contrast to these works, our approach is more 'top-down' than 'bottom-up'. Rather than accepting the limitations imposed by the incompleteness and inaccuracies inherent in existing direct observations of gross employment flows, our work accepts the restrictions of existing economic theory as an identifying assumption. Because dynamic general equilibrium theory is central to our approach, our results provide an internally consistent view of labor market dynamics and their relationship to economic activity at large.

The view of aggregate employment flows received from the afformentioned studies can be summarized in three broad strokes. First, gross worker and job flows are large compared to the corresponding net flows. Second, the average amplitude of fluctuations in the employment outflow is larger than that of the employment inflow. That is, employment reductions during recessions are more the consequence of an increase in the outward flow from employment than a decrease in the inward flow. Third, this cyclical pattern in the employment flows partly reflects a marked asymmetry in gross job flows: job destruction rises sharply during recessions and job creation is nearly acyclic. Together, these observations point to a pronounced countercyclical pattern in labor force reallocation; the available data imply that worker and job flows increase in recessionary periods and decrease during booms.

Our results support only the first strand of the received view; beyond that, they imply a strikingly different picture of aggregate labor market dynamics. All unobserved forcing variables – labor productivity, allocative efficiency, and the job separation rate – turn out to be strongly procyclical. There is little surprise regarding labor productivity; our implied measure is quite similar to traditional definitions. By contrast, our procedure implies that both allocational efficiency and the job separation rate are highly variable. More importantly, the structure of the model passes along the strong procyclical variation to gross employment flows and this delivers the startling conclusion that both the flow into employment and flow out of employment are strongly procyclical. Furthermore, the employment flows are symmetric – a property that follows from the requirement that the jointly large gross employment flows reconcile the comparatively small period-to-period observed changes in aggregate employment, i.e. the net employment flow. In marked contrast to the conventional wisdom, our results imply that the bulk of labor force reallocation occurs during booms, not recessions. Interestingly, a recent and quite systematic analysis of the CPS by Shimer (2005b), concludes that the job finding probability of a representative searching worker is strongly procyclical and the probability of separation faced by a representative employed worker is approximately acyclical. These findings are consistent with the strongly procyclical employment inflows and procyclical labor force reallocation found here, but not with the strong cyclical symmetry of the emploment inflows and outflows implied by our procedure.

In the diagnostic realm, the current paper inevitably intersects with explicit efforts – of which ours is not – to validate or invalidate the Mortensen-Pissarides framework. To our knowledge, Cole and Rogerson (1999) and Shimer (2005a) are the only such works to date. The Cole and Rogerson study documents some of the quantitative successes and failures of the Mortensen-Pissarides framework using a reduced-form approach, but do so with an eye toward replicating some of the more salient gross job flow facts in U.S. manufacturing (e.g. Davis and Haltiwanger, 1992) that we, along with Shimer (2005b), find to be an unreliable guide to aggregate employment dynamics.

Shimer (2005a) casts doubt on the quantitative applicability of the Mortensen-Pissarides framework in the form of a data puzzle. He shows that a general form of the model, which includes structural stability in matching, cannot produce the wide procyclical variation observed in the vacancy-unemployment ratio in response to quantitatively reasonable labor productivity and job destruction shocks. Our results show that with matching function instability, the socially efficient allocations implied by the Mortensen-Pissarides framework are consistent with procyclical matching efficiency and labor market mismatch. We subsequently ask whether the shocks, and their cyclical properties, provide a reasonable source of aggregate labor market fluctuations. The current study complements Shimer's as we provide a resolution to the existence of simultaneously large fluctuations in the vacancy-unemployment ratio and small fluctuations in aggregate labor productivity.

The remainder of the paper is organized as follows. Section 2 outlines our version of the Mortensen-Pissarides model and derives the theoretical restrictions that allow us to identify the unobserved shocks. In section 3, we briefly describe the observed data and its basic statistical properties. Section 4 presents the simulated method of moments procedure for determining the VAR(1) process that governs the shocks. Section 5 presents the results and analyzes the cyclical properties of job creation and destruction as well as those of the underlying shocks. Section 6 interprets these findings in the context of recent literature. We briefly outline our conclusions and set a direction for future research in Section 7.

2 The Model

The economy is inhabited by a continuum of infinitely-lived worker/households distributed uniformly along the unit interval; there is also a continuum of firms. At the beginning of each period, a worker is considered either employed or unemployed. The measure of employed workers is denoted N_t; the measure of unemployed workers is the complement $U_t \equiv 1 - N_t$. The representative household has preferences over state-contingent consumption and employment given by

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, N_t\right), \qquad 0<\beta<1, \tag{1}$$

where β is the subjective discount factor. Following Merz (1995), the period utility function is separable in consumption and employment, with

$$U\left(C_t, N_t\right)=\log C_t-\frac{N_t^{1+\frac{1}{\gamma}}}{1+\frac{1}{\gamma}}, \qquad \gamma>0,$$

where γ defines the wage elasticity of labor supply at a constant marginal utility of wealth (the "Frisch elasticity" of labor supply).

Both workers and firms must undergo a costly search process before jobs are created and output is produced. At the beginning of each period, each unemployed worker searches for a job expending ϕ consumption units in the process. Aggregate period-t search costs incurred therefore equal $\phi\left(1-N_t\right)$ consumption units. Firms create job vacancies, but only by expending κ units of output per vacancy per period, generating aggregate "recruiting" costs equal to κV_t. Here, as in the traditional Mortensen-Pissarides framework, all jobs must be posted as vacancies before they can be filled. Once a job is filled, it produces output equal to Z_t generating aggregate output

$$Y_t=Z_t N_t \tag{2}$$

where $Z_t>0$ is the exogenously determined productivity of labor.

The matching function captures the labor market search frictions. The typical formulation determines the number of job matches formed in a given period, $M\left(V_t, U_t\right)$, as an increasing function M of job vacancies, V_t, and the number of job seekers, U_t, where M exhibits constant returns to scale. With search costs ultimately arising from heterogeneity-induced information problems, we interpret the matching function as a mapping from the labor market's informational state in a given period – which implicitly includes the degree of mismatch between the characteristics of vacant jobs and searching workers – to the number of job matches formed. To allow for fluctuations in mismatch, we generalize the matching function to include a multiplicative shock term, χ_t. Hence, the number of matches formed in period t is given by

$$M_t = \chi_t M\left(V_t, U_t\right) = \chi_t V_t^{\alpha}\left(1 - N_t\right)^{1-\alpha} \tag{3}$$

where $0 < \alpha < 1$ and χ_t is the period-t realization of an unobserved shock process. Increases in χ_t raise the number matches formed given the numbers of searching workers and available positions. Consequently, fluctuations in χ_t signify improvements or deteriorations in the 'allocational efficiency' of the labor market.

While job matches are being formed, others are dissolved. We assume that the fraction of existing matches dissolved during period-t, σ_t, is also determined as the realization of an exogenous stochastic process. The period-t change in aggregate employment, i.e. the net employment flow, is defined as the difference between the period gross employment inflow and gross employment outflow:

$$N_{t+1} - N_t = M_t - \sigma_t N_t. \tag{4}$$

Note that each flow is directly impacted by unobserved shocks: the flow into employment by the allocational efficiency term, χ_t, and the outflow by the rate at which workers separate from jobs, σ_t.

The state of the economy in a given period, or (N_t, e_t), consists of the beginning-of-period employment level N_t, and values of the unobserved and exogenous state vector $e_t = (Z_t, \chi_t, \sigma_t)$. We make the standard Markovian assumption which allows agents to form expectations of future-period quantities using knowledge of the current state only. Given the current state, the socially efficient allocation of employment, vacancies, and consumption, $\{N_{t+1}, V_t, C_t\}$, solves the following recursively-defined social planner's problem:

$$\upsilon\left(N_t, e_t\right) = \max_{N_{t+1}, V_t, C_t} \left\{U\left(C_t, N_t\right) + \beta \mathrm{E}_t \upsilon\left(N_{t+1}, e_{t+1}\right)\right\} \tag{5}$$

subject to

$$C_t + \phi\left(1 - N_t\right) + \kappa V_t \leq Z_t N_t. \tag{6}$$

$$N_{t+1} = (1 - \sigma_t) N_t + \chi_t M (V_t, 1 - N_t). \tag{7}$$

where $\upsilon (N_t, e_t)$ is the future discounted social value of employment level N_t and the exogenous state e_t. Equation (6) represents the period-t resource constraint prohibiting the sum of current expenditures on consumption, job search, and vacancy creation to exceed current output, and equation (7) describes the trajectory of employment (4) with the matching function (3) determining the current-period flow into employment.

The corresponding first-order and envelope conditions imply an Euler equation describing an intertemporally efficient vacancy-posting scheme for the economy. Suppressing arguments and letting primes denote one-period-ahead quantities, we write

$$U_C \frac{\kappa}{\chi M_V} = \beta \mathrm{E}_t U'_C \left\{ Z' + \phi + \frac{U'_N}{U'_C} + \frac{\kappa}{\chi' M'_V} \left[(1 - \sigma') - \chi' M'_U \right] \right\} \tag{8}$$

equating the loss in welfare resulting from the generation of an additional vacancy with the expected future social benefit. In this expression,

$$\frac{1}{\chi M_V} = \alpha^{-1} \frac{V}{\chi M}$$

gives the average duration of vacancies multiplied by the elasticity of vacancies in matching, $\alpha = \frac{V M_V}{M}$. The left-hand side of (8), therefore, represents the utility loss associated with a marginal increase in vacancies. The expected gain of the marginal vacancy, given by the right-hand side of (8), derives from many sources. The expression $Z' + \phi + \frac{U'_N}{U'_C}$ gives the period-$(t+1)$ net social benefit flowing from an additional match formed in the current period t. The term Z' equals the output flowing from the match; ϕ gives the (constant) search costs foregone by the worker in the match. The final term in the sum, $\frac{U'_N}{U'_C}$ – negative since $U'_N < 0$ and $U'_C > 0$ – represents the consumption value of the leisure foregone by the newly matched worker. In the basic Mortensen-Pissarides setup, this quantity is a constant; here it is allowed to vary over the business cycle according to the worker's preferences.

The final term in braces represents the net future social benefit arising from the expected persistence of a job match. Given that any single current-period match survives with probability

$1-\sigma'$, future social welfare will increase simply by reducing expected future recruiting costs by the quantity $\frac{\kappa(1-\sigma')}{\chi' M'_V}$. The second term in this sum, $-\chi' M'_U$, represents the future reduction in the future job-finding rate $\frac{\chi M}{U}$ due to the current depletion of the unemployment stock; the expected recruiting cost in future consumption units equals $\frac{\kappa M'_U}{M'_V}$.

As a system, equations (6)–(8) characterize the socially-optimal allocation of employment, vacancies, and consumption given a joint distribution for the exogenous forcing variables or shocks: Z_t, χ_t and σ_t. The traditional Mortensen-Pissarides approach determines these quantities in a market equilibrium with a real wage emerging as the outcome of Nash bargaining between firms and households. The socially optimal allocation characterized above is supported by a similar market allocation mechanism provided that: 1) asset markets are rich enough for households to diversify away employment risk, and 2) the relative bargaining power between households and firms is such that the positive and negative search externalities net out to zero.[5] Although we do not take a position on the precise nature of the allocation mechanism, we maintain that existing market and institutional arrangements direct the realized allocation sufficiently close to the social optimum to establish equations (6)–(8) as a useful instrument of measure.

3 The Data

Before proceeding to shock measurement, we briefly review some of the well-known facts regarding the observed aggregate U.S. labor market measures that bear on our analysis. Given that the model presented in the previous section does not require a labor market participation decision for worker/households, we must choose whether to express our employment and unemployment variables, N_t and $U_t \equiv 1-N_t$ relative to labor force or the age 16 and over population. Although there are valid arguments in favor of both normalizations, we find that the choice little affects our results, and choose the labor force (employment plus unemployment) as our reference population. In the absence of a long time series on actual job vacancies, we follow standard

[5] Hosios (1990) determines the conditions under which the Pareto-optimum is supported as a decentralized market equilibrium in a static evironment; Merz (1995) and Andalfatto (1996) do the same in dynamic general equilibrium settings. The market equilibrium in the current work closely follows those of Merz and Andalfatto.

practice and construct vacancies from the Conference Board's help-wanted advertising index. The resulting vacancy series, V_t, is also expressed per member of the labor force. Also, since our model abstracts from the capital accumulation decision, we must choose between aggregate output and aggregate consumption – a choice that reflects our desire to preserve a consistent and well-understood labor productivity measure and one that can be more readily compared to those in other studies. Since the aggregate labor input N_t produces all goods and services, including private investment goods and those purchased by government, real GDP provides the appropriate output measure. All of our time series are constructed at the quarterly frequency and run from 1948:1 to 2003:4.

Although we are chiefly interested in the cyclical properties of these variables, it is useful to first compare their magnitudes as measured by the sample first moments: mean employment (N) equals .944 or 94.4% of the labor force, mean unemployment (U) equals .056 (5.6% of the labor force), and mean vacancies (V) equals .047 (4.7% of the labor force). The average vacancies-unemployment ratio $\left(\frac{V}{U}\right)$ equals .944. We use these values to assist in preference and technology parameter calibration.

To describe the business-cycle variation in these quantities, we follow Shimer (2005a) and remove the low-frequency trend in all variables implied by the Hodrick-Prescott filter under a smoothing parameter of 10^5. We apply this procedure to remove movements in the aggregates induced by institutional and technological changes associated with job-matching, so that they are not spuriously assigned to matching function instability arising from cyclical movements in labor market mismatch. The cyclical characteristics of the observed variables are summarized in Table 1. Employment, vacancies, and the vacancies-unemployment ratio are all strongly procyclical and persistent; unemployment is strongly countercyclical and persistent. Employment and unemployment both lag output slightly with peak correlations lagging aggregate output by one quarter. Note as well, the extreme volatility of the vacancy-unemployment ratio with a standard deviation of 37 percent around its trend. These data also affirm the Beveridge curve with a strong contemporaneous correlation between vacancies and unemployment of $-.920$.

Given that our methods imply measures of the bidirectional worker flows between employment and unemployment (or nonemployment), we briefly review some of the existing evidence regarding gross job and worker flows here. Direct evidence on the aggregate employment flows arises primarily from two sources: the gross job flow data from the U.S. manufacturing sector constructed and analyzed by Davis and Haltiwanger (1992) and Davis, Haltiwanger, and Schuh (1996), and the monthly gross flow of workers between employment, unemployment, and "not in the labor force" derived from the Current Population Survey (CPS) analyzed most extensively by Blanchard and Diamond (1990). In three broad strokes, the following picture of gross worker and job flows emerges from these works. First, gross worker and job flows are large compared to the corresponding net flows. For example, Davis et. al. (1996) report that annual manufacturing job destruction averages 10.3 percent of total manufacturing employment, and a corresponding figure for job creation of 9.1 percent. The difference, approximately the average net change in manufacturing employment, reflects the declining importance of manufacturing during their sample period. In addition, they report an average quarterly employment inflow of 9.7 percent of employment and average quarterly outflow of 9.4 percent.[6] Second, the average amplitude of fluctuations in the employment outflow (into unemployment or out of the labor force) is larger than that of the employment inflow (from unemployment and outside the labor force). That is, employment decline during recessions is more the result of an increase in the outward flow from employment than a decrease in the inward flow. Third, this cyclical pattern in the employment flows partly reflects a sharp asymmetry in gross job flows with job destruction rising more sharply during recessions than job creation falls. That is, job destruction is countercyclical and job creation is nearly acyclic. Together, these observations point to a countercyclical pattern in labor force reallocation; worker and job flows increase in recessionary periods and decrease during booms.

4 Measuring the Shocks

In this section, we present our procedure for measuring the unobserved exogenous shocks to labor productivity, matching efficiency, and the job destruction rate: $\{Z_t, \chi_t, \sigma_t\}$.

[6] Job flow averages are based on the 1972:2 - 1988:4 period; worker flow averages are based on the 1972:1 - 1886:4 sample period. Their results on worker flows rely heavily on corrected CPS measures gathered by Blanchard and Diamond (1990).

4.1 Identification and Estimation

To uniquely identify each of the shock series, the observations on employment, vacancies, and consumption $\{N_t, V_t, C_t\}$ are substituted into the theoretical restrictions comprised of equations (6), (7), and (8). We begin with the observation that the labor productivity shocks $\{Z_t\}$ are computed directly from the planner's resource constraint (6), given the histories of the three observed, endogenous variables:

$$Z_t = \frac{C_t + \phi(1 - N_t) + \kappa V_t}{N_t}.$$

Given our calibration of the technology parameters ϕ and κ (discussed below), the aggregate search and recruiting costs (the latter two terms of the numerator) sum to only one percent of steady state output. Coupled with our simplification allowing measured real GDP to proxy model consumption, Z_t is nearly identical to the traditional average product of labor definition of labor productivity.

With $\{Z_t\}$ so computed and substituted into the intertemporal efficiency condition (8), only equations (8) and (7) remain in play. These equations along with inferred labor productivity and the observed endogenous variables jointly imply realizations of allocational efficiency and the job separation rate: $\{\chi_t\}$ and $\{\sigma_t\}$. Although computing these series requires surmounting the usual technical hurdle imposed by evaluating the conditional expectation characteristic of the intertemporal efficiency condition, it is instructive to gather some intuition regarding the procedure by first examining the perfect foresight case: with the unobserved, exogenous forcing variables treated as deterministic sequences, the conditional expectation is vanquished from equation (8).

First, we examine the implications of the equation of motion (7) reconciling net employment changes $N_{t+1} - N_t$ as the difference between the employment inflow, $\chi_t M(V_t, 1 - N_t)$, and the employment outflow, $\sigma_t N_t$. Suppose for the moment that the matching function is structurally stable, or equivalently, allocational efficiency is acyclical, i.e. $\chi_t = \chi$ all t. Under this assumption, the job separation rate is computed as

$$\sigma_t = \frac{\chi M(V_t, 1 - N_t) - (N_{t+1} - N_t)}{N_t}$$

using the observations on vacancies and employment. The result, although not apparent from the expression, contradicts conventional wisdom: the job separation rate turns out to be procyclical, rising during booms and falling during recessions. Instead, suppose that χ_t is allowed to vary under the assumption that the job separation rate is constant or acyclical: $\sigma_t = \sigma$ all t. Then, χ_t, computed as

$$\chi_t = \frac{N_{t+1} - N_t + \sigma N_t}{M(V_t, 1 - N_t)},$$

turns out to be countercyclical, falling during booms and rising during recessions. This signals higher degrees of labor market mismatch during recoveries than recessions – a view that is consistent with recessions as periods of 'cleaning up,' but also one which is potentially inconsistent with an intertemporally efficient allocation of vacancies.

To investigate this possibility, we next turn to the perfect foresight version of the intertemporal efficiency condition (8). For the sake of analysis, the equation is expressed as

$$\kappa \left[\frac{U_C}{\beta U'_C} \frac{1}{\chi M_V} - \frac{1 - \sigma'}{\chi' M'_V} \right] = Z' + \phi + \frac{U'_N}{U'_C} - \frac{\kappa M'_U}{M'_V} \tag{9}$$

separating the expressions containing the unobserved exogenous shock terms, χ and σ, from those containing exclusively observed variables. The right-hand side expression, containing only observed variables, is sharply countercyclical in spite of the fact that labor productivity (Z') is procyclical. Ignoring the constant search-cost term, ϕ, the final two terms on the right-hand side are both countercyclical. The intuition behind the countercyclical behavior of $\frac{U'_N}{U'_C}$ – the rate at which the representative worker/household demands consumption units in exchange for additional labor time – is straightforward. During booms, or periods of high employment and high consumption, the marginal disutility of work increases and the marginal utility of consumption decreases; the opposite is true during recession. Given that the term is negative, it displays countercyclical behavior. The final term, given parametrically by

$$\frac{\kappa M_U'}{M_V'} = \kappa \frac{1-\alpha}{\alpha}\frac{V'}{U'}, \tag{10}$$

represents the future vacancy costs imposed by the current draining of the unemployment pool to fill available positions. Given that it directly inherits the strongly procyclical nature of the vacancy-unemployment ratio, its negative sign makes it strongly countercyclical. And, though our calibration of κ and α implies considerable damping of the extreme variation in the vacancy-unemployment ratio, the remaining cyclical variation in $\frac{\kappa M_U'}{M_V'}$ strongly dominates that generated by $\frac{U_N'}{U_C'}$, so that even if the latter term is held constant (as the traditional Mortensen-Pissarides framework implies), the right-hand side of (9) remain strongly countercyclical.

To see how the unobservables χ and σ must respond to maintain the equality in (9), it is useful to approximate the persistence in the marginal utility of consumption and allocational efficiency by equating current-period variables with the corresponding one-period-ahead variables: $U_C = U_C'$ and $\chi = \chi'$. With these approximations, the perfect foresight intertemporal efficiency condition (9) reduces to

$$\frac{\kappa}{\chi' M_V'}\left[\frac{1}{\beta} - 1 + \sigma'\right] \approx Z' + \phi + \frac{U_N'}{U_C'} - \frac{\kappa M_U'}{M_V'} \tag{11}$$

Since increases in allocational efficiency correspond to decreases in the left-hand side of this relation, a constant rate of job separation σ' implies countercyclical allocational efficiency χ', large in recessions, small during booms. Alternatively, given that increases in the rate of job separation σ' produce increases in the left-hand side, fixing allocational efficiency implies a procyclical job separation rate, small in booms and large during recessions. Therefore, the perfect foresight approximation of our model economy does not lead us to a quick answer regarding the broad cyclical properties of allocational efficiency and the job separation rate. Given average labor productivity inferred from the aggregate resource constraint (8), the equation-of-motion for employment and the deterministic Euler equation, taken separately, imply opposing comovements for each. Whereas the equation-of-motion for employment requires procyclical allocational efficiency and a countercyclical job separation rate, the deterministic Euler equation implies countercyclical allocational efficiency and a procyclical job separation rate.

We now proceed to the complete measurement procedure to produce a unique realization of unobserved shocks that jointly satisfy the observed data and the theoretical restrictions of the model. To overcome the usual analytical hurdles introduced by solving (8), we proceed by log-linearizing the system (6)–(8) around its steady state. Dropping the time subscript to denote steady-state values and using lower-case letters to represent the corresponding log-deviation from steady-state, we define the endogenous variables as follows: $n_t \equiv \ln\left(\frac{N_t}{N}\right)$, $v_t \equiv \ln\left(\frac{V_t}{V}\right)$, and $c_t \equiv \ln\left(\frac{C_t}{C}\right)$. The log-deviations of exogenous variables are similarly defined: $z_t \equiv \ln\left(\frac{Z_t}{Z}\right)$, $\widetilde{\chi}_t \equiv \ln\left(\frac{\chi_t}{\chi}\right)$, and $\widetilde{\sigma}_t \equiv \ln\left(\frac{\sigma_t}{\sigma}\right)$. To complete the conditional evaluation of expectations, we must complement the log-linearized efficiency conditions with a VAR(1) structure to the exogenous shocks:

$$\widetilde{e}_{t+1} = A\widetilde{e}_t + \varepsilon_{t+1} \tag{12}$$

where $\widetilde{e}_t = (z_t, \widetilde{\chi}_t, \widetilde{\sigma}_t)'$, A is a 3×3 matrix of constants, and $\varepsilon_t = \left(\varepsilon_{zt}, \varepsilon_{\widetilde{\chi}t}, \varepsilon_{\widetilde{\sigma}t}\right)'$ is trivariate normal with $\mathrm{E}\varepsilon_t = 0$ and $\mathrm{E}[\varepsilon_t\varepsilon_t'] = \Sigma$.

Given values for the nine parameters comprising the VAR(1) matrix of coefficients A, the decision rules mapping the period-t state $(n_t, s_t, \widetilde{e}_t)$ into values for the endogenous variables (n_{t+1}, v_t, c_t) are required to be log-linear as follows:

$$\begin{bmatrix} n_{t+1} \\ v_t \\ c_t \end{bmatrix} = \Pi \begin{bmatrix} n_t \\ z_t \\ \widetilde{\chi}_t \\ \widetilde{\sigma}_t \end{bmatrix}, \qquad \Pi = \begin{bmatrix} \pi_{nn} & \pi_{nz} & \pi_{n\widetilde{\chi}} & \pi_{n\widetilde{\sigma}} \\ \pi_{vn} & \pi_{vz} & \pi_{v\widetilde{\chi}} & \pi_{v\widetilde{\sigma}} \\ \pi_{cn} & \pi_{cz} & \pi_{c\widetilde{\chi}} & \pi_{c\widetilde{\sigma}} \end{bmatrix} \tag{13}$$

where the π parameters are expressions comprised of technology and preference parameters. Easy manipulation segregates the observed variables from the unobserved exogenous variables:

$$\begin{bmatrix} n_{t+1} - \pi_{nn}n_t \\ v_t - \pi_{vn}n_t \\ c_t - \pi_{cn}n_t \end{bmatrix} = \widehat{\Pi} \begin{bmatrix} z_t \\ \widetilde{\chi}_t \\ \widetilde{\sigma}_t \end{bmatrix}, \qquad \widehat{\Pi} = \begin{bmatrix} \pi_{nz} & \pi_{n\widetilde{\chi}} & \pi_{n\widetilde{\sigma}} \\ \pi_{vz} & \pi_{v\widetilde{\chi}} & \pi_{v\widetilde{\sigma}} \\ \pi_{cz} & \pi_{c\widetilde{\chi}} & \pi_{c\widetilde{\sigma}} \end{bmatrix}. \tag{14}$$

Given data series for employment, vacancies, and consumption, the left-hand side of this expression is a vector of constants in any given period. With values of all model parameters in hand, the matrix $\widehat{\Pi}$ is easily inverted to yield the period-t realization of the forcing process: $(z_t, \widetilde{\chi}_t, \widetilde{\sigma}_t)$. Also, substituting the sequence of shock realizations $\{z_t, \widetilde{\chi}_t, \widetilde{\sigma}_t\}_{t=0}^{T}$ into the VAR(1) process (12) determines the underlying realizations of innovations: $\left\{\varepsilon_{zt}, \varepsilon_{\widetilde{\chi}t}, \varepsilon_{\widetilde{\sigma}t}\right\}_{t=1}^{T}$. Of course, all of this assumes knowledge of the unknown constants in Π. Although there is sufficient independent evidence to calibrate the technology and preference parameters that help comprise these constants, the same cannot be said of the unknown coefficients of matrix A. In the absence of useful a priori information concerning the stochastic properties of the forcing variables, the available time series evidence must be filtered through the theoretical identifying restrictions to infer these characteristics.

Assuming values for technology parameters (α, κ, ϕ), preference parameters (β, γ), and unconditional steady-state values $(N, V, U, C, Z, \chi, \sigma)$, we must determine the 15 parameter values of the vector $\boldsymbol{\theta}$ comprised of the 9 coefficients of the 3×3 VAR(1) coefficient matrix, A, and the 6 independent parameters of the 3×3 variance-covariance matrix of innovations, Σ. Given that our model is singular by construction, it yields a large number of moments to serve as parameter selection criteria. Furthermore, since the unobserved forcing variables represent all of the residual variation that is left behind by theory and observation, we choose 15 moment conditions for an exact identification of parameters values. Thus, we define $\boldsymbol{\theta}$ as

$$\boldsymbol{\theta} = \arg\min_{\boldsymbol{\theta}} \; [\mathsf{m} - \mathsf{m}(\boldsymbol{\theta})]' [\mathsf{m} - \mathsf{m}(\boldsymbol{\theta})]$$

minimizing the distance between a 15-dimensional vector of theoretical moments $\mathsf{m}(\boldsymbol{\theta})$ and the corresponding 15-dimensional vector of observed data moments, m.[7] The theoretical moments, however, involve unobserved exogenous variables, and so cannot be determined analytically. As a consequence, we apply the simulated method of moments (SMM) procedure advocated by Ingram and Lee (1991), substituting simulated moments for the theoretical moments. We refer the interested reader to Appendix B for further details of the estimation procedure.

[7] The vector $\boldsymbol{\theta}$ must therefore also solve the 15-equation nonlinear system $\mathsf{m}(\boldsymbol{\theta}) = \mathsf{m}$.

4.2 Calibration

With a large empirical literature to draw upon and stationary labor market variables at hand, we combine micro-evidence with long-run data averages to calibrate the steady state values of the exogenous shocks and the technology parameters. We begin by setting the steady state values of the labor market variables, N_t, V_t, and U_t, equal to the corresponding data first moments: $N = .944$, $V = .047$, and $U = .056$. Given these values, we observe that the steady-state version of the equation-of-motion for employment (7), or

$$\sigma N = \chi V^{\alpha} U^{1-\alpha}, \tag{15}$$

sharply restricts the steady state values of the shocks, χ_t and σ_t, and matching technology parameter, α. Based on Blanchard and Diamond's (1989) estimates of the U.S. aggregate matching function, we set α equal to .6. The steady state rate of job separation is chosen to be 10 percent of total employment per quarter, or $\sigma = .10$, based on the CPS worker flow data reported by Davis, et. al. (1996) that uses the correction of Abowd and Zellner (1985). Under these settings, the steady state employment condition (15) subsequently pins down steady state allocative efficiency level: $\chi = 1.856$. These values imply steady state gross employment flows of $\sigma N = M = .094$ per quarter, or 9.4 percent of the labor force. Furthermore, the average duration of a vacancy, $(M/V)^{-1}$, implied is .502 quarters or about 45 days, reproducing the value reported by van Ours and Ridder (1992) using data from the Dutch economy (although their number is not explicitly a target in our calibration). The implied unemployment duration is .599 quarters, or 54 days.

Without loss of generality, we normalize the steady state of inferred aggregate output to equal one, $ZN = 1$, yielding steady-state labor productivity $Z = 1/N = 1.06$. Under this assumption, the steady state resource constraint becomes

$$C + \phi U + \kappa V = 1.$$

Note that in the absence of search and recruiting costs, i.e. $\phi = \kappa = 0$, labor productivity reduces to the traditional average product of labor definition. Steady state labor productivity equals C^{-1} in that case. (Recall that we must proxy consumption with aggregate output, or real GDP.) In the presence of search and recruiting costs, our imputed output measure deviates from measured real GDP somewhat, but we anticipate the magnitude of the difference to be small, with the settings of parameters ϕ and κ largely determining the gap. Unlike the model's other parameters, independent evidence regarding these two parameters is scarce. We follow Andalfatto (1996) in assuming steady state recruiting expenditures to be one percent of output, or $\kappa V = .01$, implying $\kappa = .211$; with no better information regarding the cost of search borne by workers, we assume that steady state search costs are likewise one percent of aggregate output, $\phi U = .01$, yielding $\phi = .177$. The steady state value of consumption is therefore $C = .98$, or 98 percent of output.

Finally, we consider the two preference parameters, β and γ, the subjective discount factor and the Frisch elasticity of the labor supply, respectively. We choose $\beta = .99$ consistent with a steady-state risk-free real interest rate of 4 percent. We follow Merz's (1995) interpretation of the empirical literature and choose $\gamma = 1.5$ for the Frisch elasticity.

5 Results

In this section we characterize the dynamic properties of the forcing variables – labor productivity, allocational efficiency, and the job separation rate – and those of gross employment flows that follow from the former. We first discuss the properties of these five series as if they are products of pure measurement. In other words, we assume that our version of the Mortensen-Pissarides model suffers no misspecification errors implying accurate time series measurement of the exogenous forcing variables and corresponding gross employment. We subsequently address the possibility of model misspecification.

The simulated method-of-moments procedure discussed in the previous section determines the following point estimates defining (12), the joint distribution of shocks:

$$A = \begin{bmatrix} .58083 & .00646 & -.00437 \\ .05589 & .44310 & -.14951 \\ .28616 & -.40217 & .29534 \end{bmatrix}$$

and

$$\Sigma = \begin{bmatrix} .000002 & -.000017 & -.000068 \\ - & .000719 & .001748 \\ - & - & .005290 \end{bmatrix}.$$

We now turn to the time series realizations of these shocks as implied by the realized innovations $\{\varepsilon_{zt}, \varepsilon_{\widetilde{\chi}t}, \varepsilon_{\widetilde{\sigma}t}\}$, (12), and the above estimate of the VAR(1) coefficient matrix A.

5.1 Cyclical Properties of the Shocks

The statistics reported in Table 2 provide our first glimpse of the dynamic behavior of exogenous shocks; corresponding characteristics of inferred output are also reported for benchmark comparisons. In interpreting these statistics, it should be recalled that inferred output is nearly identical to actual output measured by real GDP due to the relatively small size of aggregate search and recruiting costs (and equivalently, that model consumption is nearly identical to aggregate output). For each shock series, we examine: 1) volatility, or the amplitudes of the fluctuations around trend measured by the percentage standard deviation from trend, 2) the comovements of the variables as measured by the contemporaneous correlations with inferred output, and 3) phase shifts measured by locating peak correlations with output over a domain of four lags and four leads.

We begin by noting the standard univariate properties of aggregate output: its typical deviation from trend is roughly 2 percent and is quite persistent with an autocorrelation function that reveals a steady but inertial decline in the linear dependence upon past values. As anticipated from numerous prior studies, average labor productivity is strongly procyclical and displays roughly one-half the variation of output. It is a bit more persistent than aggregate output and has no tendency to lead or lag the cycle.[8]

[8] In contrast, labor productivity constructed using an hours measure of the labor input tends to lead the cycle by a quarter or two. See Kydland (1995).

Turning our attention to the dynamics of allocational efficiency and the job separation rate, we see that both display conspicuous deviations about trend, especially the job separation rate. The 30.3 percent standard deviation about trend in allocational efficiency is roughly 14 times that of aggregate output and gives clear support to the hypothesis that the matching function is structurally unstable. The job separation rate, with a standard deviation equal to 47.7 percent trend, is approximately 22 times more volatile than output. As the case with labor productivity, allocational efficiency and the job separation rate are strongly procyclical, and both show contemporaneous correlations of about .90. Both are persistent, but less so than aggregate output and labor productivity; job separation is less persistent than allocational efficiency. These properties are plainly evident in Figures 1–3 which display the time series plot of each forcing variable against inferred output. We defer our discussion of these findings and for now, simply note that they are clearly consistent with the view that much of the interesting behavior of labor markets is buried in the gross employment flows.

5.2 Gross Employment Flows

Our measurements of labor market allocational efficiency and the aggregate job separation rate imply time series histories for the gross employment flows between the state of unemployment and employment (or not employed). In model terms, the period-t employment inflow equals $\chi_t M(V_t, 1 - N_t)$; the period-t outflow equals $\sigma_t N_t$.

Before reporting our measures of gross labor flows, we feel it important to caution against using industry-level data on gross job and worker flows to infer corresponding aggregate properties. Since industry-level employment flows are subject to significant leakage – e.g. workers leave manufacturing for other sectors, and vice versa – the cyclical characteristics of the inflows and outflows can differ markedly. Aggregate quantities, of course, are not exposed to intersectoral leakages. Additionally, job flows are conceptually distinct from employment flows: the latter include movements associated with the flow of workers separate from the flow of jobs (e.g. quits and layoffs). Given that aggregate net employment flows are small – the average absolute quarterly flow averages .27 percent of the labor force with a standard deviation from trend of only .40 percent – it is impossible for the bidirectional gross employment flows to inherent such strong cyclical asymmetry. If gross flows are large in the aggregate, then cyclical properties of the inflows and outflows must be nearly identical. Any sharp increase or decrease in one, must be matched by a similarly sharp increase or decrease in the other, to maintain the narrow difference between the two, i.e. the comparatively small net employment change. By implication, the gross employment flows are fairly symmetric in their cyclical properties and either flow captures well the movements in labor reallocation over the cycle.

The relevant question is then two-fold. First, are the gross flows highly variable? If so, are they jointly procyclical, countercyclical, or neither? Adherence to the conventional view that aggregate employment inflows are procyclical (perhaps mildly) and employment outflows are countercyclical is certain to produce disappointment; one pillar must fall. The statistics in Table 2 are revealing. We first note that our procedure produces gross employment flows that are indeed highly variable. Both display standard deviations roughly 45% standard deviation from trend with the inflow slightly more volatile. Next, we see that the correlations of the gross flows with contemporaneous output at four leads and lags reveals both to be strongly procyclical and persistent. Thus, it is the cyclical behavior of the inferred employment outflow that defies conventional wisdom. Here, it is procyclical, rising during booms and declining during recessions, along with the flow into employment. The statistics in Table 2 also reveal a pronounced phase separation of one flow from the other, with the employment outflow correlating with output most strongly during the leading periods relative to the inflow. This indicates that the employment outflow tends to lead the inflow. Figure 4, plotting the log-deviations from trend of both flows, convincingly illustrates both the tight procyclical relationship and the phase shift. The lagging characteristic of the employment inflow mirrors the well-known tendency for total employment to increase in the wake of recessionary periods. The shaded regions depict recession periods designated by the National Bureau of Economic Research (henceforth, NBER).

Finally, we investigate the primitive levels of the gross flows implied by steady state levels and the log-deviations shown in Figure 5. As reported earlier, the calibration of our model implies steady state gross flows of .094 workers per member of the labor force per quarter. Figure 8 indicates that the imputed employment flows range between 2 percent to 24 percent of the labor force per quarter. This figure clearly shows the procyclicality of the implied gross flows, rising during expansions and reaching a peak before each NBER-defined recession, subsequently falling through the recession-period, occasionally reaching a trough well after the NBER-recession ending date. To gain perspective on the magnitude of this variation, Davis, Haltiwanger, and Schuh (1996) report quarterly job destruction rates (jobs destroyed as a fraction of employment) in their 1972:2–1988:4 quarterly sample period ranging between 3 percent and 11 percent per quarter. In comparing these figures, one must keep in mind that our method allows for worker flows not captured by changes in job flows. Given, that Davis, et. al. also estimate that total job reallocation (roughly the sum of job creation and job destruction) only accounts for between one-third and one-half of total worker reallocation, the variation in their manufacturing job destruction flow is comparable in magnitude to the variation in gross employment flows computed here for the entire economy.

6 Discussion

6.1 The mechanics

We begin our analysis of the results by identifying the mechanisms of the model that act in concert with the more salient cyclical properties of the observed data to produce the results highlighted in the previous section. Motivated by the persistent, procyclical movements of labor productivity Z_t (Table 2, Figure 1), and the impulse response functions suggesting an independent role of the labor productivity shock (Figures 4-6), we first trace out the dynamics engendered by our DGE version of Mortensen-Pissarides model in response to a sudden and persistent increase in labor productivity, holding constant allocational efficiency χ_t and the rate of job separation σ_t. Due to persistence, a current shock, i.e. innovation, signals greater future productivity as captured by the term Z' in the intertemporal efficiency condition (8), producing a current increase in vacancies as firms respond to the higher anticipated productivity benefits of filled positions. Consequently, additional job matches form in the period of impact – matches that become productive in the ensuing period – thereby increasing employment and reducing unemployment. These effects are summarized by an increasing vacancies-unemployment ratio.

The innovation in labor productivity also sets in motion forces that work to reduce the vacancy-unemployment ratio. To see this, one first notes that the resource constraint (6) translates the ensuing anticipated increase in future productivity and employment into an increase future consumption through an augmented flow of output.[9] The increases in employment and consumption subsequently reduce the representative worker's marginal willingness to substitute non-market activities for consumption, i.e. decreases $\frac{U'_N}{U'_C}$ in equation (8). This offsets to some extent an individual firm's propensity to create vacancies and the attending increase in employment. Furthermore, the current reduction in the employment pool persists and offsets some of the future benefits of currently high productivity by frustrating future hiring efforts through the term $-\frac{\kappa M'_U}{M'_V}$. This term represents the additional future recruiting costs exacted by the depleted stock of searching workers on the right hand side of (8). Recall that this last quantity (or more precisely, its absolute value) is directly proportional to the vacancy-unemployment ratio – a proxy for the 'tightness' of the labor market. The data, as we have seen, displays extremely large procyclical variation in this ratio, and casts doubt on the model's ability to produce the required cyclical variation in response to realistically sized shocks to labor productivity.[10]

By allowing both matching efficiency and the job separation rate to vary over the business cycle, our identification procedure responds to this tension by, in effect, equating the observed vacancy-unemployment ratio with the socially optimal one in each period. The highly variable and procyclical allocative efficiency shock χ_t (Table 2, Figure 2) effectively increases the expected gains of vacancy creation in the face of an exogenous increase in labor productivity, thus generating additional vacancies while also increasing the rate at which unemployed workers meet up with them. As a result, the flow of workers from unemployment to employment increases, reducing the unemployment pool. The increase in vacancies coupled with the decrease in unemployment, thus gives an additional upward push to the vacancy-unemployment ratio moving the economy along the Beveridge curve in accord with the data. Although the vacancy-employment ratio is moving decidedly in the proper direction, it cannot do so with a sizeable increase in net employment, all else constant. As aggregate employment revealing

[9] The sum of search and vacancy-creation costs, $\phi(1 - N_t) + \kappa V_t$, small and the increase in vacancy-creation costs κV_t counteract the reduction in search costs $\phi(1 - N_t)$.

[10] This point is convincingly demonstrated by Shimer (2005) using a more conventional Mortensen-Pissarides model with a structurally stable matching function. We are indebted to his work for articulating the opposing forces on the theoretical vacancy-unemployment ratio restraining its response to labor productivity shocks.

relatively small period-to-period changes, a complete picture of labor market dynamics requires more employment outflow to restock the unemployment pool depleted by greater efficiency in matching. This element, of course, is provided by the procyclical rate of job separation σ_t (Table 2, Figure 3).

Given that these labor market dynamics are largely driven by systematic variation in the allocative efficiency of the labor market, it is instructive to study the implied average durations of vacancies and unemployment spells over the cycle. In the standard setting, the stable matching function forms the basis for monotonic mappings of the vacancy-unemployment ratio into the durations: increasing for vacancies, decreasing for unemployment. Given that the observed vacancy-unemployment ratio is strongly procyclical, a stable matching function produces average vacancy durations that fall during recessionary periods and rise during booms, with opposite movements for the unemployment durations. By contrast, the durations implied by the matching function multiplied by our procyclical allocational efficiency series are both countercyclical, with unemployment durations up much more sharply than vacancy durations during recessionary periods. Figure 6 clearly shows this cyclical behavior, with the average unemployment duration reaching nearly 5 quarters during 1982, an extreme event by this measure, and the corresponding vacancy duration reaching roughly 1.5 quarters. Figure 7 compares the average vacancy durations implied by a stable matching function (χ set to its steady state value) versus the one implied by the inferred allocative efficiency series; Figure 8 show the corresponding comparison for the average unemployment durations. Qualitatively, the countercyclical behavior of vacancies implied by the current approach is at odds with the traditional, stable matching function model. Quantitatively, the procedure implies cyclical variation in average employment durations well in excess of those implied by a stable matching function.

The implication of procyclical labor force reallocation is broadly consistent with recent and independent work by Shimer (2005b) who infers aggregate job finding and job separation probabilities from employment, unemployment, and unemployment duration data based on the Current Population Survey of the BLS. Although he finds the job finding probability to be strongly procyclical as in the current study, the job separation probability is nearly acyclical. Additionally, Shimer's strongly procyclical job finding probablility is reflective of our strongly countercyclical average unemployment duration. The combined effect, of course, implies the procyclical labor force reallocation property that is found by our procedure, but not the tight procyclical symmetry between the flows that we derive as a consequence of matching the period-to-period changes in aggregate employment. Both studies, nonetheless, imply a radical change in thinking regarding behavior of employment flows over the business cycle from the wisdom received from the manufacturing job flow studies (Davis and Haltiwanger, 1992 and Davis, Haltwanger, and Schuh, 1996) and earlier analysis of worker flows based on the CPS data (Blanchard and Diamond, 1990).

6.2 Measurement: Implications for Business Cycles

Here, we briefly play the devil's advocate role and treat our findings as pure measurement, and discuss the implications for our understanding of labor market dynamics and business cycles.

Perhaps the most striking result is the procyclical behavior of labor force reallocation, with NBER recession periods consistently marked by falling gross employment flows. Adjusted worker flow data derived from the CPS indicates the reverse pattern. In their analyses of these data, Davis, et. al. (1996) conclude that "the countercyclical behavior of both inflows and outflows is consistent with the view that recessions are periods of intense restructuring activity in the economy" (p. 134).[11] In a similar vein, Blanchard and Diamond (1990) conclude that the asymmetrically large cyclical fluctuations in the employment outflow compared to those of the employment inflow "rules out a Schumpeterian view of cyclical fluctuations, with booms as times when inventions are implemented yielding high job creation." The CPS data is instead consistent with the popular view of recessions as 'cleansing' mechanisms, or periods in which unproductive firms, jobs, and techniques are erased from the productive system. In other words, recessions should be marked by substantial factor reallocation, including labor reallocation, in comparison to booms.

[11] In making this statement, they are mindful of the strength of comovements linking aggregate worker flows and manufacturing job flows. Their measures of manufacturing job destruction and aggregate unemployment inflows both rise sharply during recessions and bear a high contemporaneous correlation (0.71); although employment outflows display less cyclical variation, its contemporaneous correlation to job destruction is nonetheless substantially positive (0.47). The statistical linkage between unemployment ouflows and employment inflows on the one hand, and job creation on the other, is much weaker (contemporaneous correlations of 0.16 and 0.22).

At the level of the unobserved shocks, the procyclical pattern of labor reallocation is produced by the twin procyclical forces of allocative efficiency (χ_t) and the rate of job separation (σ_t). According to our interpretation, declining allocative efficiency during recessionary periods is symptomatic of a widening gulf between the locations and skills of unemployed workers, and the locations and required skills of firms with vacancies. That is, recession are periods when the symmetric incomplete information problem of labor market search is aggravated, and hence it is comparatively difficult for firms and workers to form productive matches. The reduced rate of job destruction complements this view. Figures 7 and 8 offer another perspective on this phenomenon, showing the strong tendency for both average vacancy durations and unemployment durations to rise during recessions, presumably indicating a large number of potential job matches that are foregone. If cleansing is to be temporally concentrated at all, the results indicate that it will occur during booms, when productivity, matching efficiency, and job separation are all on the rise.

Save for the cyclical timing, we maintain that the picture of labor market dynamics and business cycles is decidedly Schumpeterian. Again, we note that labor productivity, the rate of job separation, and allocational efficiency are all procyclical. In the Schumpeterian perspective, productivity improvements stem from innovative flurries and rapid technology adoption that leads to the 'creative destruction' of unproductive jobs and rapid reallocation of the labor force. The comparatively high rates of job separation (σ_t) measured during boom periods reflect not only involuntary separations from creative job destruction, but also increased quits as workers capitalize on better opportunities. The improved allocational efficiency of labor markets (χ_t) during these periods signals an amelioration of the two-sided information problems as more matches are formed from a given number of vacancies and searching workers. It is as if a significant proportion of the work force, queued in either unemployment or unproductive jobs during recessions, are gradually matched in more productive jobs as recession gives way to the 'productivity-storm' of a boom. As new opportunities are created, so are incentives for the reallocation of the labor force across activities and locations. In a descriptive vein, our perspective on business cycle dynamics improves upon the Schumpeterian one as it does not produce labor productivity that is counterfactually countercyclical.

6.3 Diagnosis: Implications for Theory

Perhaps the most striking of our results is the implied procyclicality of the gross aggregate employment flows in the face of the conventional wisdom received from incomplete survey data implying countercyclical (and asymmetric) flows. By itself, we do not feel that the aberration is sufficient to declare the model invalid as measurement device. The CPS data on gross worker flows is notoriously unreliable. A number of systematic biases inherent in the measurement procedure have been identified and corrective measures proposed.[12] Even more disturbing from our point of view, however, is that these data do not yield the net employment changes implied by the published data, and often the implied net change is of the wrong sign. As we have already stressed, if we require that the employment flows reconcile with the net changes and accept, *a priori*, the notion that the gross flows are large, asymmetry in the measured flows cannot prevail – inflows and outflows must rise and fall together over the cycle. As for manufacturing job flow data, it represents a small and declining proportion of U.S. economy: manufacturing employment currently accounts for approximately 10 percent of total employment. In contrast, our employment flows exactly reconcile the observed aggregate net employment changes and are, by construction, comprehensive.

Two of three theoretical identifying restrictions imposed by the model are sufficiently transparent and without controversy. The resource constraint (6) along with observed data provides an aggregate labor productivity measure Z_t that is nearly identical to the standard output per worker definition of aggregate labor productivity. The equation-of-motion for employment (7) defines a simple flow-stock reconciliation.

The intertemporal efficiency condition (8), by comparison, is rich with content. We have already examined the perfect foresight version of this equation in Section 4 in motivating our measurement procedure. In that analysis, we paid some attention to the role played by the strongly procyclical nature of expression (10) which represents the future recruiting costs exacted as a consequence of running down the stock of unemployed persons to fill current positions. This expression shows these costs to be determined solely by the technological aspects of match-

[12] Blanchard and Diamond (1990) and Davis, et. al. (1996) report results using data based on adjustments proposed by Abowd and Zellner (1985).

ing, and inherit its strongly procyclical behavior directly from the pronounced procyclicality of the vacancy-unemployment ratio. Much of the identification burden is thus placed on the precise specification of the matching function, i.e. the constant-returns Cobb-Douglas matching function (3) which implies a unit constant elasticity of substitution between the two matching inputs of vacancies and unemployment.

As an alternative to Cobb-Douglas, consider the more general constant elasticity of substitution (CES) matching function

$$M\left(V_t, U_t\right) = \left[\alpha V_t^{-\rho} + (1-\alpha)\, U_t^{-\rho}\right]^{\frac{\eta}{\rho}},$$

where $-1 < \rho < \infty$ determines the elasticity of substitution, $\frac{1}{1+\rho}$, and $\eta > 0$ determines the returns to scale. Under the CES specification, expression (10) becomes

$$\frac{M'_U}{M'_V} = \frac{1-\alpha}{\alpha}\left(\frac{V'}{U'}\right)^{1+\rho}. \tag{16}$$

Note that as $\rho \to -1$, the ratio $\frac{M'_U}{M'_V}$ becomes constant and equal to $\frac{1-\alpha}{\alpha}$. That is, as unemployment and vacancies become perfect substitutes in matching, the degree of measured procyclical variation in the term $\frac{M'_U}{M'_V}$ is reduced to zero, and consequently, so is its corresponding influence in the intertemporal efficiency condition for vacancies (8). The economics of this result are as follows.[13] In terms of (8), an exogenous increase in labor productivity (Z') raises the value of a filled position relative to the value of non-market activities (U'_N/U'_C) and search costs foregone (ϕ), thereby encouraging the substitution of vacancies for unemployment leading to an increase in the vacancies-unemployment ratio. With great ease of substitution between vacancies and unemployment in matching, the magnitude of this response is large. In relation to our results, the exogenous increases required from the allocational efficiency χ and the job separation rate σ in producing a large observed increase in the vacancy-unemployment ratio diminishes with increases in the substitutability of the matching inputs.[14] Note also that the returns to scale

[13] This intuition mirrors that given by Shimer (2005) in his diagnostic evaluation of the Mortensen-Pissarides model.

[14] Shimer, however, notes that Blanchard and Diamond's (1989) 0.74 point estimate of the elasticity of substitution goes the other way, but not with enough precision to reject the Cobb-Douglas unit elasticity case. With less substitutability, even more forcing is required from χ and σ.

parameter η drops from expression (16), implying that a resolution is not to be found in the thickness of market externalities.

Finally, we briefly mention a weakness arising not from theory *per se*, but in the inexact mapping between the model variables and observed endogenous variables. In particular, we made the simplifying assumption that output is either consumed or used up in the labor market search process. Given that the latter component is small, our model is akin to a representative agent asset-pricing model with equilibrium consumption equal to output. To proxy aggregate consumption, we opted for the aggregate output measure of real GDP (per member of the labor force) over the consumption of nondurables and services. The primary advantage of this approach is in keeping our measure of labor productivity as close as possible to the traditional average product of labor definition. Given their strong cyclical similarities – consumption is strongly procyclical and only a bit less variable than real GDP – we do not expect that a switch from an output-based consumption measure to actual consumption would reverse our main results. The alternative is to complicate the model by admitting investment and capital accumulation. By producing another efficiency condition, the set of theoretical restrictions increases from three to four, necessitating the definition of another unobserved exogenous variable and an increase in the number of parameters to be estimated from 15 to 24, significantly increasing the computational burden. This extension is beyond the scope of this paper, but research is ongoing to shed light on this and the other aforementioned issues.

7 Conclusion

We have demonstrated that the Mortensen-Pissarides model of labor market search combined with the observed time series for aggregate output, employment, and vacancies is consistent with considerable procyclical variation in both the allocative efficiency of labor markets and the rate of job separation. Given that the model exactly reconciles observed net employment changes with gross employment flows, and that the data determines the net employment changes from period-to-period, the model and data also imply measures for the employment inflow and outflow. Much of this result is simple arithmetic. The small and procyclical period-to-period changes observed in aggregate employment, combined with large predicted gross employment flows, implies virtually identical cyclical characteristics in inflows and outflows. In the aggregate, no asymmetry in employment flows can be observed. They are either both procyclical or both countercyclical and our results imply that they are procyclical.

Our investigation into the mechanics of the DGE search model that, along with the data, produces these results, echoes Shimer's (2005a) diagnostic exploration of Mortensen-Pissarides framework. He shows that subjecting the more conventional environment, which includes a stable matching function, to reasonably sized shocks in labor productivity and job separation cannot produce the substantial variation in the vacancy-unemployment ratio evinced by the data. In contrast, our procedure allows the allocational efficiency of the labor market to vary along with labor productivity and the job separation rate, so that the search model achieves a perfect fit with the observed data, including the marked variation in the vacancy-unemployment ratio. The simultaneous procyclical variation required of both labor market allocative efficiency and the job separation rate provides an alternative interpretation of Shimer's conclusions regarding the Mortensen-Pissarides model. Additionally, our conclusion that labor force reallocation is procyclical is broadly consistent with Shimer's (2005b) analysis of the CPS data which finds procyclical job finding probabilities and nearly acyclical job separation probabilities.

The results also shed light on the nature of business cycle fluctuations. Perhaps most importantly, they do not support the cleansing hypothesis, or the view that recessions are periods of intense factor reallocation that clears inefficient firms, jobs, and production techniques from the productive system. Conceptually, the cleansing hypothesis has a close kinship with the Schumpeterian notion of creative destruction, wherein innovations and technology adoption provide the catalyst for factor reallocation. Both views imply that factor reallocation is clustered during recessionary periods. Our results deliver the opposite cyclical timing: labor reallocation is concentrated during booms, not recessions. If cleansing is to occur, it is to occur during the expansionary phase of the cycle. Our results do not rule out Schumpeterian creative destruction, only its timing. This modification of the standard Schumpeterian cyclical schematic actually improves it standing with the facts as it does not imply counterfactually countercyclical labor productivity.

Our procedure has forced all of the about-trend variation in aggregate output, unemployment, and vacancies that cannot be understood by the Mortensen-Pissarides framework into the three exogenous variables: labor productivity, the job separation rate, and allocative efficiency. We expect that we have therefore overstated the magnitude of fluctuations in allocative efficiency, the job separation rate, and the implied gross employment flows. With part of the paper's stated mission as 'pre-theoretical,' i.e. a guide to future theoretical research, we recognize that the exogenous forcing variables may not indeed be truly exogenous. Our hope is to stimulate further research into the nature of our findings to generate even richer theoretical structures which will eventually weaken the measurement content of our exogenous labor market state.

Appendix

A The Data

Unemployment, U, is the unemployment rate (unemployed persons per member of the labor force) constructed as a quarterly average of the seasonally adjusted monthly series from the Current Population Survey (CPS) of the Bureau of Labor Statistics (BLS); series downloaded from the CPS home page http://www.bls.gov/cps.

Employment, N, is computed as the identity $N = 1 - U$.

The vacancies series, V, represents vacancies per member of the labor force and is constructed by multiplying two seasonally adjusted monthly series – the ratio of help-wanted advertising to unemployed compiled by the Conference Board (downloaded as variable LHELX from the DRI Basic database), and the unemployment rate U (defined above) – and averaging the monthly values to obtain the quarterly series. The commonly reported help-wanted advertising index is a scalar transformation of this series.

Consumption, C, is proxied by aggregate output per member of the labor force. The output variable is real gross domestic product (billions of chained 2000 dollars, seasonally adjusted annual rate) downloaded from the Federal Reserve Bank of St. Louis FRED II database at

http://research.stlouisfed.org/fred2/series/GDPC1.

We divide this series by the seasonally-adjusted civilian labor force (averaged from monthly to quarterly), appropriately scaled, to express the variable in year 2000 chained dollars per person. The civilian labor force measure is constructed by the Bureau of Labor Statistics (BLS) as part of the Current Population Survey (CPS) and is downloaded from http://www.bls.gov/cps.

B Estimation of VAR(1) Shock Process

As explained in section 4, solving the model to ultimately recover the histories of the exogenous forcing processes, requires that we complement the log-linearized versions of the efficiency conditions (6)–(8) with the VAR(1) system (12) summarizing the probability characteristics of the shocks:

$$\widetilde{e}_{t+1} = A\widetilde{e}_t + \varepsilon_{t+1}$$

where $\widetilde{e}_t = (z_t, \widetilde{\chi}_t, \widetilde{\sigma}_t)'$, A is a 3×3 matrix of constants, and $\varepsilon_t = \left(\varepsilon_{zt}, \varepsilon_{\widetilde{\chi}t}, \varepsilon_{\widetilde{\sigma}t}\right)'$ is trivariate normal with $\mathrm{E}\varepsilon_t = 0$ and $\mathrm{E}[\varepsilon_t \varepsilon_t'] = \Sigma$. Given that we have no information, a priori, regarding the 15 distributional parameters comprising the vector $\boldsymbol{\theta}$ – the 9 parameters of the VAR(1) coefficient matrix A and the 6 independent parameters of the variance-covariance matrix Σ – we determine them using a simulated method of moments procedure. Thus, the vector $\boldsymbol{\theta}$ is chosen to minimize the objective function

$$Q(\boldsymbol{\theta}) = \left[\mathsf{m} - \mathsf{m}(\boldsymbol{\theta})\right]' \left[\mathsf{m} - \mathsf{m}(\boldsymbol{\theta})\right]$$

where $\mathsf{m}(\boldsymbol{\theta})$ is a 15×1 vector of simulated theoretical moments that are implied by the model, and m is the corresponding 15×1 vector of data moments. The data moments are simple sample averages:

$$\mathsf{m} = \frac{1}{T} \sum_{t=1}^{T} \mathsf{m}_t, \quad i = 1, \ldots, 15,$$

where $T = 224$ is the number of time series observations in our sample of observed exogenous variables.

Given technology and preference parameters, the estimation procedure is initiated with three additional pieces of information: 1) an initial guess of the unknown parameters $\boldsymbol{\theta}_0$, 2) a $3 \times nT$ draw from a univariate standard normal distribution forming the random matrix u', where $T = 224$, and $n = 10$, and 3) the initial state-vector $(n_1, \widetilde{e}_1)$. By fixing the 9 coefficients of matrix A, the initial guess $\boldsymbol{\theta}_0$ determines the exact log-linear decision rules (13); it also determines the 6 independent values of the variance-covariance matrix Σ. Given u and Σ, we generate the $3 \times nT$ random matrix $\boldsymbol{\varepsilon}'$, a draw from the trivariate normal distribution $N(\mathsf{0}, \Sigma)$, as follows. Let R be the Cholesky decomposition of Σ so that $R'R = \Sigma$ where R is an upper triangular 3×3 matrix. The random draw of innovations from the trivariate normal density is then constructed as $\boldsymbol{\varepsilon} = \mathsf{u}R$, where $\boldsymbol{\varepsilon}$ is the realization $\varepsilon_t' = \left(\varepsilon_{zt}, \varepsilon_{\widetilde{\chi}t}, \varepsilon_{\widetilde{\sigma}t}\right)_{t=1}^{nT}$.

Next, we create a model simulation nT periods in length beginning from an initial state equal to the steady state: $(n_0, \widetilde{e}_0) = (0, \mathbf{0})$. Given the initial draw of innovations $\{\varepsilon_t\}_{t=1}^{nT}$, we solve (13) forward producing a simulation nT periods in length, discarding the first 10 percent of simulated data observations to remove potential bias due to initial conditions. The simulated theoretical moments are then computed using the remaining $T^* = (0.9)(nT) = 2016$ simulated data observations:

$$\mathsf{m}(\boldsymbol{\theta}) = \frac{1}{T}\sum_{i=1}^{T^*} \mathsf{m}_i(\boldsymbol{\theta}), \quad i = 1, \ldots, 15.$$

Given these simulated moments, we locate the parameter vector $\boldsymbol{\theta}$ that minimizes the expression $Q(\boldsymbol{\theta})$. The initial $\boldsymbol{\theta}$ is subsequently replaced with $\boldsymbol{\theta} = \arg\min Q(\boldsymbol{\theta})$, and the next iteration begins. The algorithm continues in this fashion until $Q(\boldsymbol{\theta}) < \delta$, where δ is sufficiently close to a machine zero to deem the most recent computed $\boldsymbol{\theta}$ the solution. The estimation requires that the same set of innovations be used at each function evaluation ensuring that any reduction in $Q(\boldsymbol{\theta})$ is due to a better $\boldsymbol{\theta}$, and not to a different set of innovations. This clearly poses a challenge to identify the true vector of structural parameters that minimize $Q(\boldsymbol{\theta})$ in our problem because Σ is the parameter that determines the process which generates the random innovations necessary for the simulations. This problem is solved by exploiting the fact that a joint normal distribution of three random variables could be generated from standard normal distribution given the parameters defining means and variance of the joint process. Hence, at each function evaluation we use the same $3 \times T$ random sample, ε, from a standard normal distribution. This implies that the set of innovations (z, χ and σ) are generated using this ε and the updated Σ at each step.

In practice, the minimization problem includes two additional constraints. First, for the exogenous shock process to be stationary, the VAR(1) coefficient matrix A needs to possess eigenvalues that lie within the unit circle. Second, the variance-covariance matrix Σ is naturally positive semi-definite. Since it is impossible to impose these two constraints explicitly in the minimization procedure, our algorithm assigns an arbitrarily large number $\left(10^{30}\right)$ to the value of the objective function whenever either of these two constraints is violated. Given an initial guess for $\boldsymbol{\theta}$, this ensures that the algorithm attains a minimum that satisfies these restrictions.

We determine the moments to be matched with three considerations in mind. First, and most obviously, the distributional parameters that we estimate do not affect the first moments of the endogenous variables implied by the non-stochastic steady state. Hence, we choose dynamic covariances between endogenous variables. Second, given that the dynamic behavior of employment is central to our analysis, the second moments relating employment to aggregate output at various leads and lags are included. Finally, it is straightforward to choose moments that show considerable variation with the parameter vector $\boldsymbol{\theta}$. Given that $\boldsymbol{\theta}$ primarily determines the dynamic behavior of the exogenous forcing variables z, χ, and σ, second and higher order moments of these will generate the most substantial variation. Unfortunately, these are not observed. The model property allowing labor productivity to be inferred directly from the social planner's feasibility constraint ameliorates this problem somewhat, and thus we apply a considerable number of moments that relate to z. With these considerations in mind, we match the following 15 moments: cov(n_t,z_{t-2}), cov(n_t,z_{t-1}), cov(n_t,z_t), cov(n_t,z_{t+1}), cov(n_t,z_{t+2}), cov(n_t,c_{t-2}), cov(n_t,c_{t-1}), cov(n_t,c_t), cov(n_t, c_{t+1}), cov(n_t,c_{t+2}), cov(z_t,z_{t-2}), cov(z_t,z_{t-1}), var(z_t), cov(z_t,z_{t+1}), and cov(z_t,z_{t+2}).

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Table 1. Cyclical Behavior of Observed Labor Market Variables.

		Cross-correlation of output with:								
Variable (x)	%SD	$x\,(t-4)$	$x\,(t-3)$	$x\,(t-2)$	$x\,(t-1)$	$x\,(t)$	$x\,(t+1)$	$x\,(t+2)$	$x\,(t+3)$	$x\,(t+4)$
Output (Real GDP)	2.15	.331	.520	.724	.884	1.000	.882	.716	.510	.327
Employment (N)	1.01	.086	.264	.485	.700	.853	.872	.789	.635	.463
Unemployment (U)	17.1	−.072	−.257	−.485	−.699	−.850	−.869	−.790	−.641	−.468
Vacancies (V)	20.6	.193	.396	.606	.768	.863	.832	.730	.557	.353
V/U	37.0	.141	.340	.562	.752	.875	.867	.775	.609	.415

Table 2. Cyclical Behavior of the Forcing Variables.

		Cross-correlation of output with:								
Variable (x)	%SD	$x\,(t-4)$	$x\,(t-3)$	$x\,(t-2)$	$x\,(t-1)$	$x\,(t)$	$x\,(t+1)$	$x\,(t+2)$	$x\,(t+3)$	$x\,(t+4)$
Inferred Output (Y)	2.15	.331	.520	.724	.884	1.000	.882	.716	.510	.327
Exogenous Forcing Variables:										
Productivity (Z)	1.40	.445	.609	.766	.859	.925	.724	.521	.317	.161
Allocational Efficiency (χ)	30.2	.240	.455	.676	.843	.905	.844	.707	.528	.352
Job Separation Rate (σ)	47.7	.175	.376	.598	.785	.896	.874	.767	.595	.406
Gross Employment Flows:										
Inflow ($U \rightarrow N$)	44.9	.148	.376	.614	.794	.868	.806	.668	.481	.288
Outflow ($N \rightarrow U$)	44.7	.097	.308	.545	.746	.865	.839	.732	.538	.337

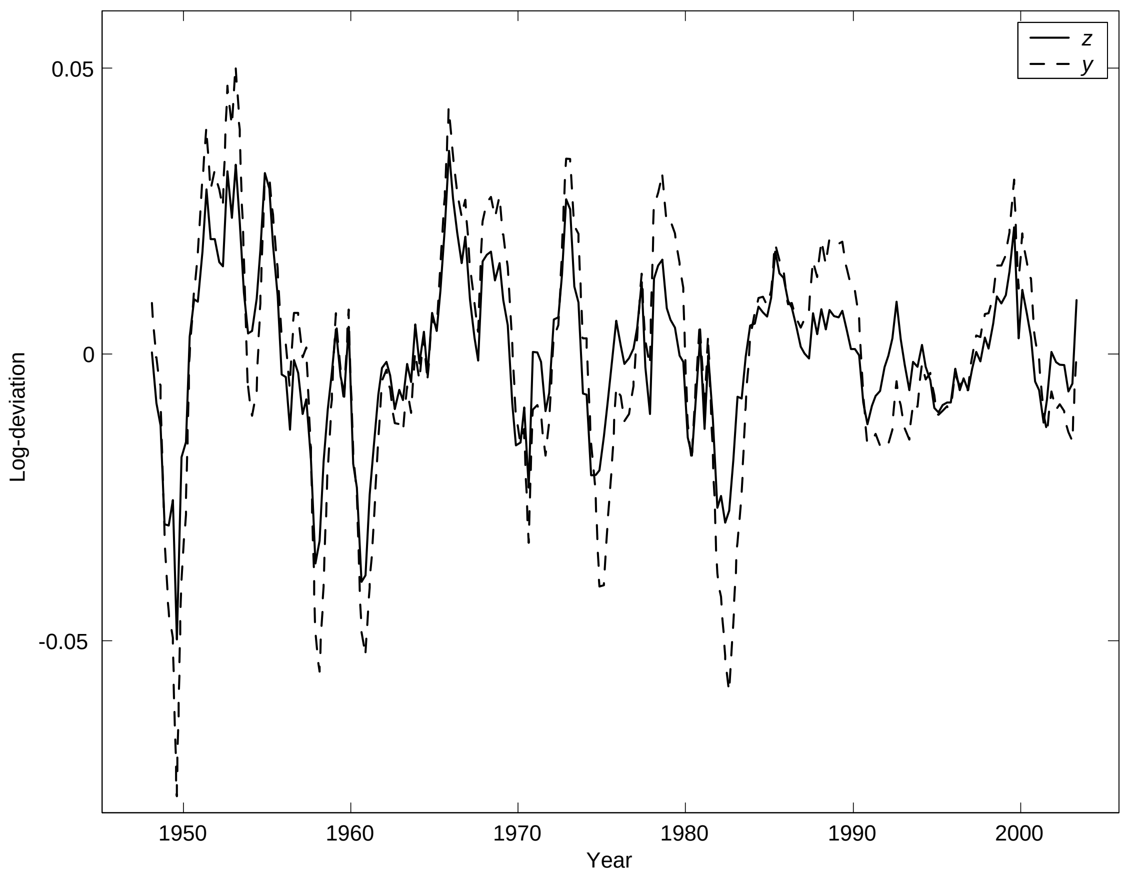

Figure 1: Labor productivity shock (solid) and inferred aggregate output (dashed).

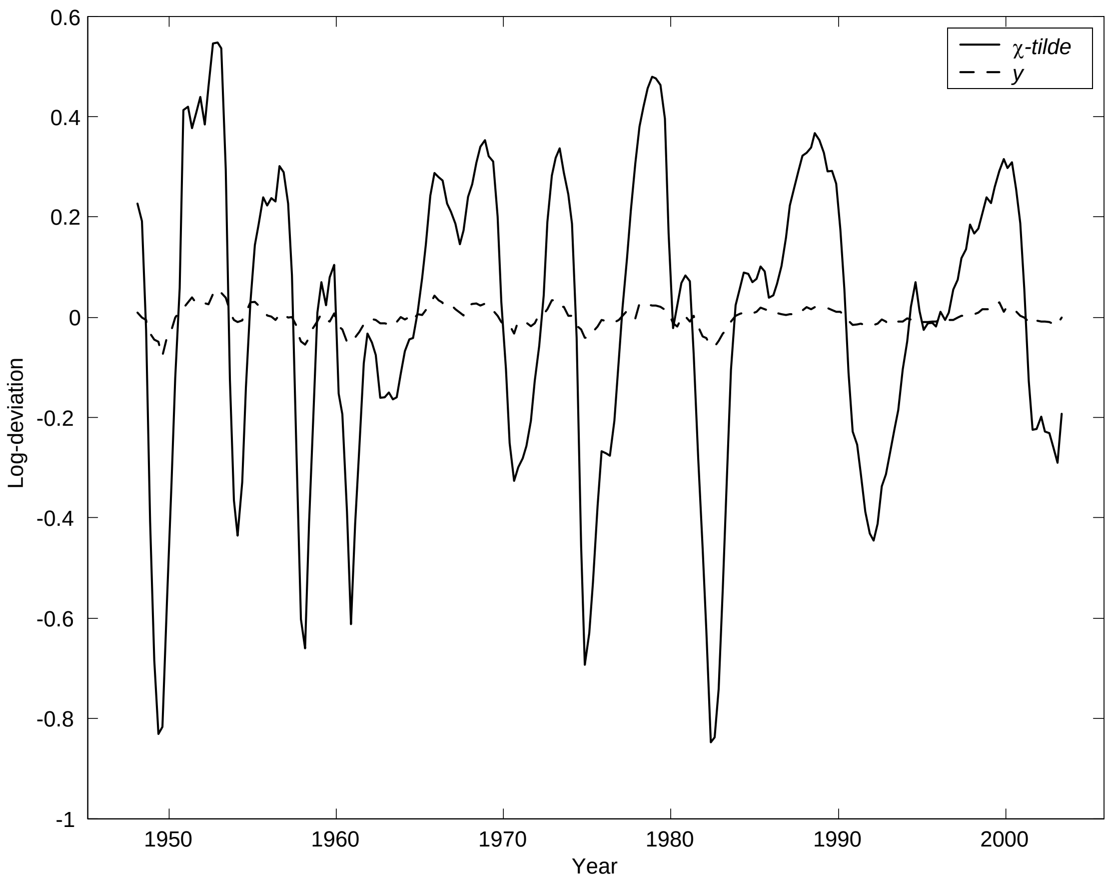

Figure 2: Allocational efficiency shock (solid) and inferred aggregate output (dashed).

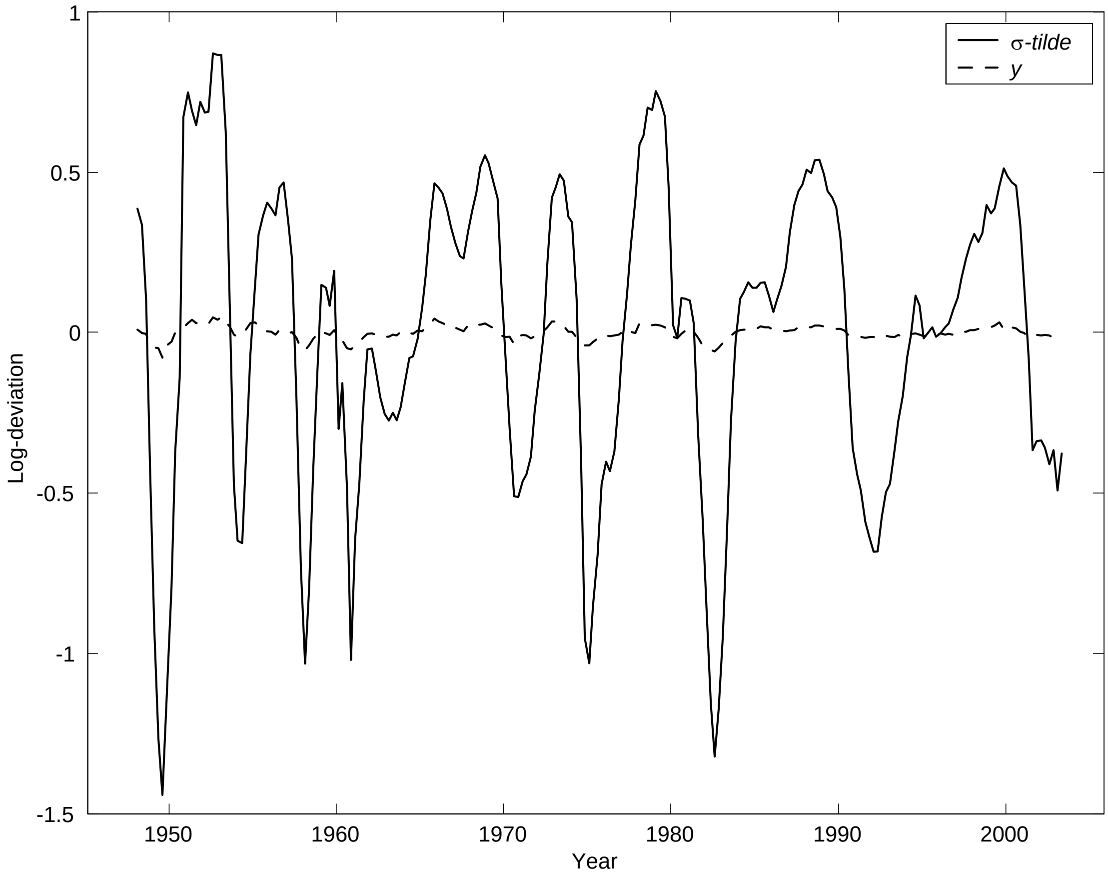

Figure 3: Rate of job separation shock (solid) and inferred aggregate output (dashed).

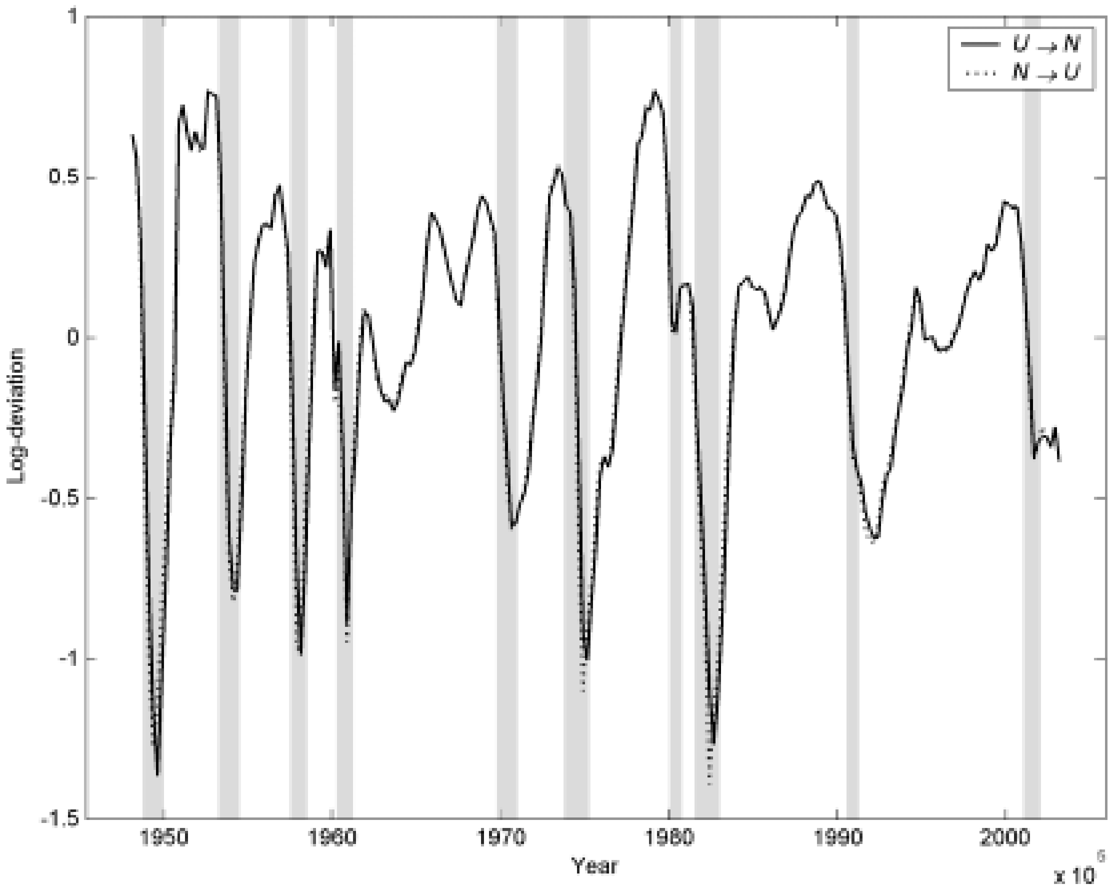

Figure 4: Implied employment inflow (solid line) and outflow (dotted line): log-deviations from trend.

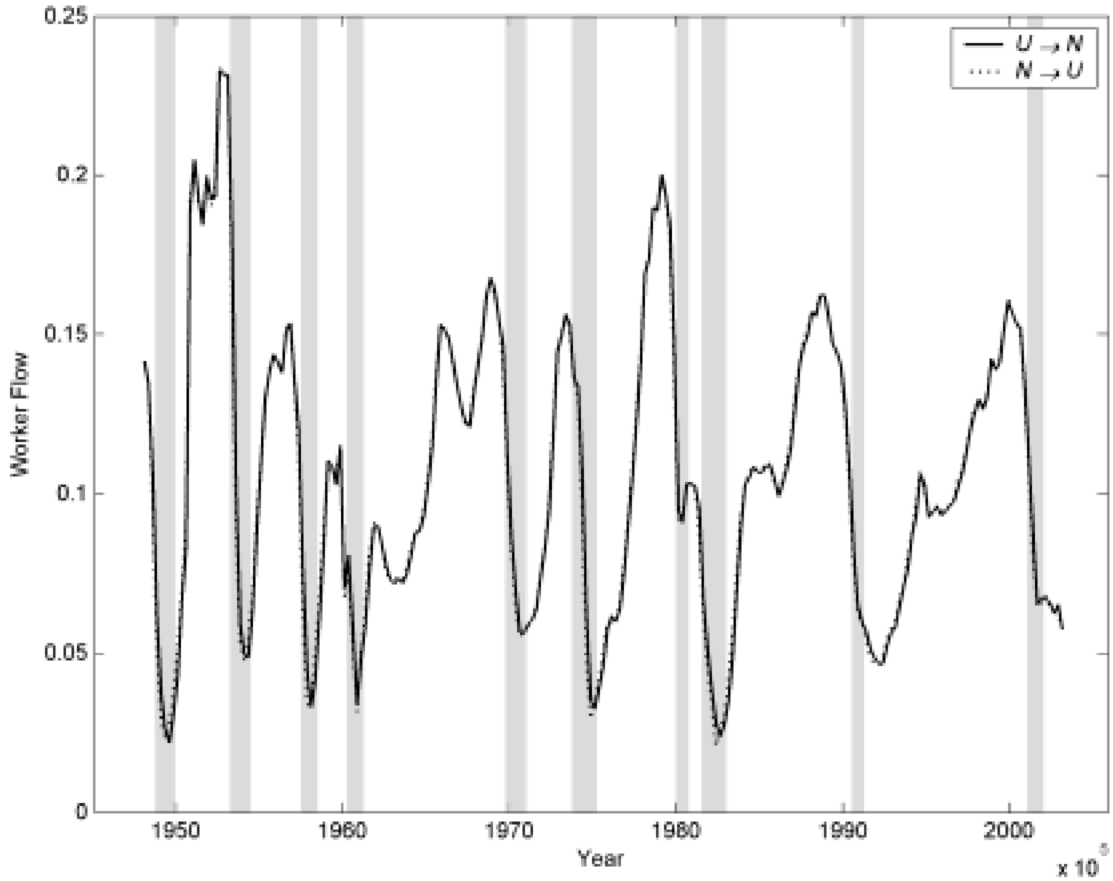

Figure 5: Implied employment flows per member of the labor force per quarter: inflow (solid line) and outflow (dotted line).

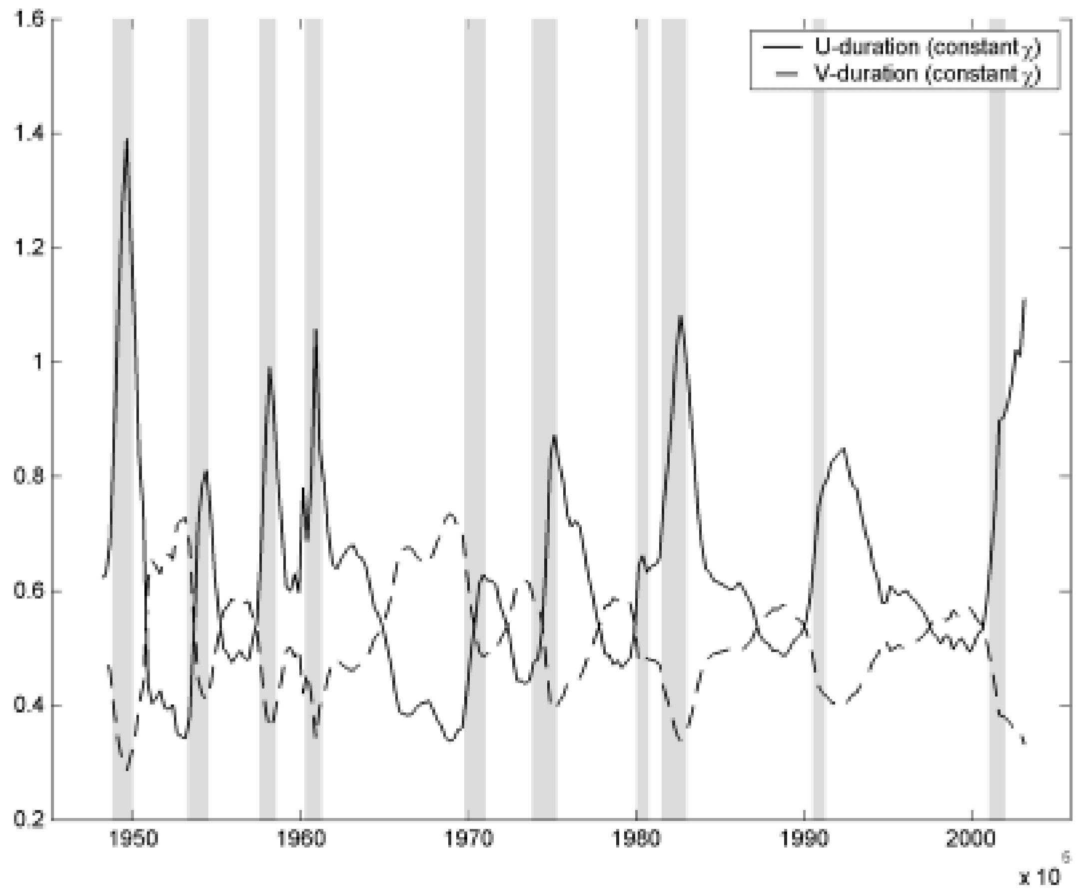

Figure 6: Implied average durations in quarters: unemployment (solid line) and vacancies (dashed line).

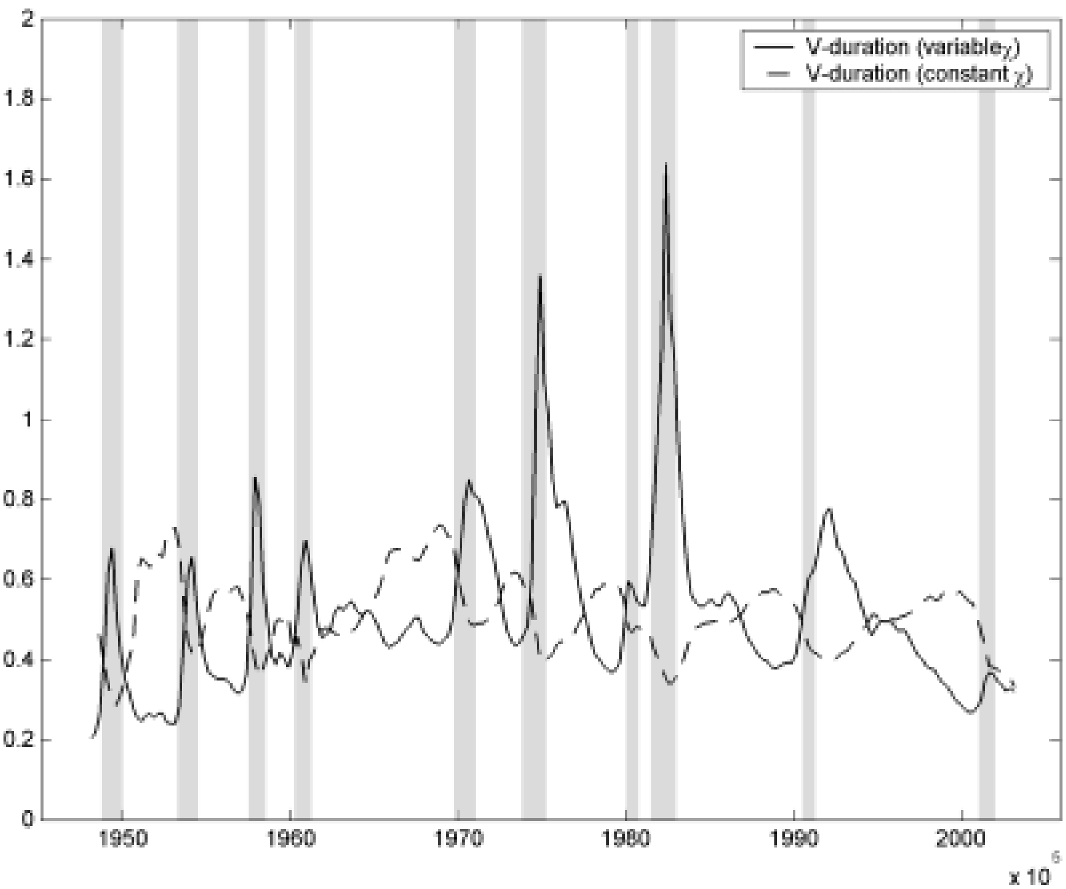

Figure 7: Implied vacancy durations in quarters: variable allocational efficiency (solid line) and constant allocational efficiency (dashed line).

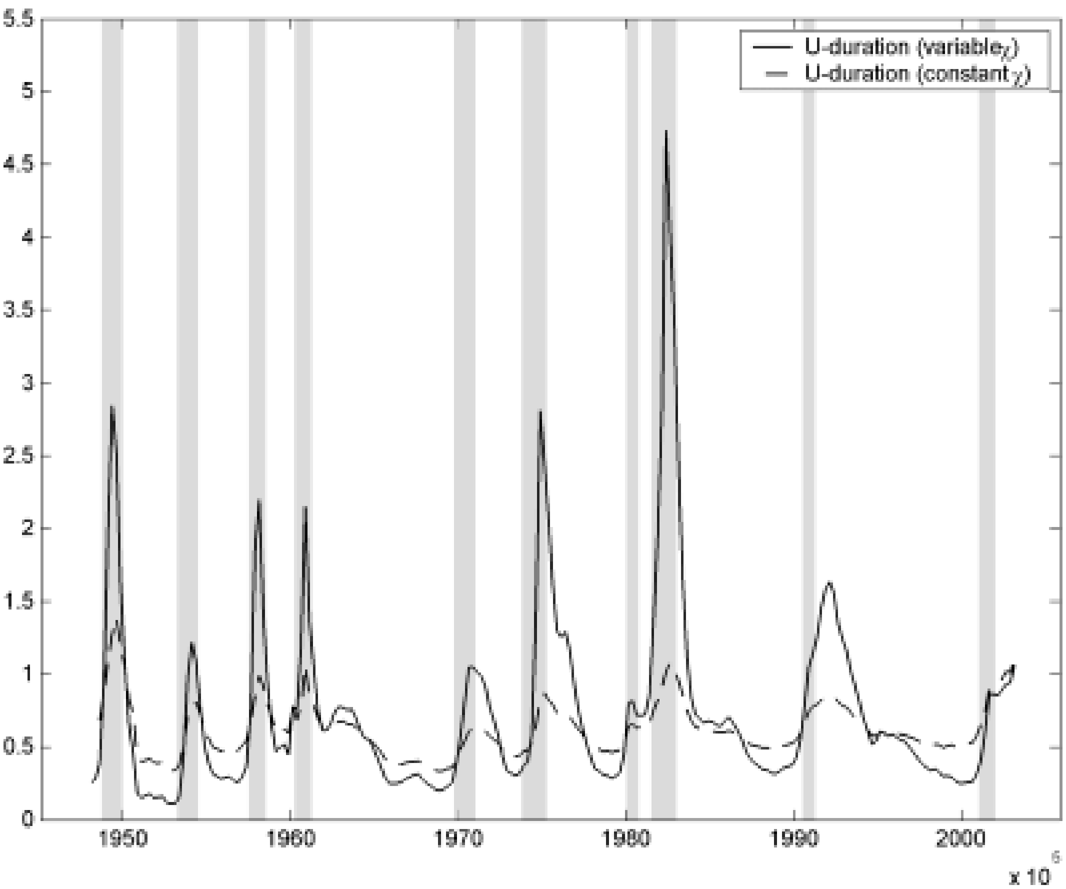

Figure 8: Implied unemployment durations in quarters: variable allocational efficiency (solid line) and constant allocational efficiency (dashed line).