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Diagnosing Labor Market Search Models: A Multiple-Shock Approach

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We construct a multiple shock, discrete time version of the Mortensen-Pissarides labor market search model to investigate the basic model's well-known tendency to underpredict the volatility of key labor market variables. In addition to the standard labor productivity shock, we introduce shocks to matching efficiency and job separation. We conduct two set of experiments. First, we estimate the joint probability distribution of shocks that simultaneously satisfy the observed data and the first-order conditions of the multiple-shock model, and then simulate its properties. Although the multiple-shock model generates significantly more volatility while preserving the Beveridge curve relationship, it generates counterfactual implications for the cyclicality of job separations. Using a business cycle accounting approach, we design the second set of experiments to isolate the sources of model incompleteness and show that the model requires significant procyclical and volatile matching efficiency and counterfactually procyclical job separations to render the observed data without error. We conjecture that the basic Mortensen-Pissarides model lacks mechanisms to generate sufficiently strong labor market reallocation over the business cycle, and suggest nontrivial labor force participation and job-to-job transitions as promising avenues of research.

Key words: Labor Market Search; Mismatch; Business Cycles; Unemployment; Job Vacancies.

JEL classification: E24; E32; J64.

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1 Introduction

There is now a fairly rich literature using the Mortensen-Pissarides labor market search model to understand business cycle movements in the labor market.[1] Although the model matches key qualitative features of the data, it has been criticized on its inability to make sense of the large volatility observed in labor market variables. In particular, Shimer (2005a) argues that implausibly large shocks to either labor productivity or job separation are required to produce the observed variation in unemployment, vacancies, and the vacancy-unemployment ratio–a finding that has come to be known as the "amplification puzzle."[2] He also finds that the job separation shock experiments produces counterfactual qualitative implications. We investigate whether an additional and plausible shock to the labor market can satisfactorily resolve this puzzle. Specifically, we add a "matching efficiency" shock to the labor market while simultaneously allowing for labor productivity and job separation shocks.

Our approach is diagnostic in nature and is similar to one taken by Chari, Kehoe, and McGrattan (2007) to estimate a stochastic process for the shocks that jointly satisfy the model's first-order conditions and monthly U.S. observations on unemployment, job vacancies, and real output. Unlike Shimer (2005a), ours is a multiple-shock approach that considers all exogenous shocks jointly. Simulations of the model indicate that the additional sources of exogenous variation augment the productivity shock to produce employment fluctuations large enough to resolve the amplification puzzle, but only at a significant descriptive cost. Our results show that large and procyclical matching efficiency shocks must be accompanied by large and procyclical job separation shocks. Although we know of no evidence to cast doubt on procyclical matching efficiency, there is plenty to indicate that the job separation rate is in fact countercyclical.

[1] For a textbook treatment of this class of models see Pissarides (2000). Broadly speaking, we can identify two separate but closely related strands in this literature. The first group, including works by Andolfatto (1996), den Haan, Ramey, and Watson (2000) and Merz (1995, 1999), incorporates labor market search into otherwise standard real business cycle environments to improve upon their cyclical implications for labor market variables such as employment. A second group of papers, such as Cole and Rogerson (1999) and Mortensen and Pissarides (1994), focuses on the implications of the standard labor market search model in relation to the empirical evidence on job creation and job destruction provided by Davis and Haltiwanger (1992) and Davis, Haltiwanger, and Schuh (1996).

[2] Earlier studies either failed to address the magnitude of the exogenous forcing process (Mortensen and Pissarides (1994), Cole and Rogerson (1999)) or implied a counterfactually positive relationship between unemployment and vacancies (Andolfatto (1996), Merz (1995)). Merz (1995) provides two versions of the model, one with constant and one with variable search effort. To be precise, her version with variable search effort gives this counterfactual finding.

To delve deeper into the descriptive shortcomings of the model, we decompose actual employment fluctuations into the three sources of exogenous variation. Specifically, we generate the innovations of the exogenous shock process that are necessary for the model to produce a perfect fit to the endogenous variable data sample. We then decompose the variation in employment contributed by each of the three potential sources. To do this we take the three innovation shock series generated by the perfect-fit experiment and expose them to the model individually with the remaining shocks held constant at steady state values. The results of these experiments point to potentially productive modifications of the basic model. Of these, we conclude that a theoretical expansion of the pool of searching workers, especially by the incorporation of job-to-job transitions, is the most natural and promising.

This paper relates to various other studies. Our investigation into the mechanics of the standard labor market search model echoes Shimer's (2005a) own diagnostic exploration of the Mortensen-Pissarides framework. Although our objective for this experiment is diagnosis rather than measurement, it is similar in approach to Chari, et. al. (2007) and the multiple-shock approach to real business cycle analysis introduced by Ingram, Kocherlakota, and Savin (1994). More recently, Cheremukhin and Restrepo-Echavarria (2010) and Pescatori and Tasci (2011) conduct business cycle accounting exercises using models with search frictions where the focus is on the "wedge" between the marginal rate of substitution between consumption and leisure and the real wage. Our starting point in the paper is the model of Merz (1995) although we abstract from the capital stock. Finally, we discuss our findings and several avenues for future research in conjunction with the literature that tries to resolve the amplification puzzle presented by Shimer (2005a).

The remainder of the paper is organized as follows. Section 2 provides a motivation behind our modeling strategy. Section 3 outlines our version of the Mortensen-Pissarides model. In Section 4, we briefly describe the data and its basic statistical properties. Section 5 discusses our calibration and estimation strategy and presents the simulation results. Section 6 analyzes the simulation results and presents our perfect-fit experiment. We also interpret our findings in the context of recent literature. We briefly outline our conclusions and set a direction for future research in Section 7.

2 Motivating the Multiple-Shock Approach

Our multiple-shock approach provides roles for exogenous shocks to labor productivity, matching efficiency, and the rate of job separation. Labor productivity shocks, common to most equilibrium models of the business cycle, are well understood. This section provides our motivation for incorporating two more sources of exogenous variation into the benchmark model that are somewhat more unconventional. Since the main mission of the paper is a diagnostic one, we look for sources of model incompleteness or misspecification in the properties of the exogenous shocks that simultaneously fit the data and the theoretical restrictions of the model. This exercise, in the spirit of the business cycle accounting research program, is to help identify productive avenues for further research.

The shock to the matching function captures the efficiency with which existing labor market institutions pair searching workers with available jobs. Andolfatto (1996) refers to this type of shock as affecting the "allocative efficiency" of labor markets; we will use the term "matching" efficiency to refer specifically to the shock. Alternatively, the rate of job separation is equal to the fraction of employed persons that will separate from their jobs in a given period. As in the most basic Mortensen-Pissarides model, the rate of job separation is exogenous in our model, but we allow it to vary randomly over time. To keep the model parsimonious and to facilitate comparison to previous work (e.g. Shimer 2005a) we do not model separations endogenously.

The matching function conveniently summarizes the labor market search process by reducing employment inflows to a simple function of unemployment and job vacancies. At its core lies the notion of labor market 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). As a reduced form formulation, the matching function shoulders a heavy burden transforming what is fundamentally an extraordinarily complex process into a convenient device to generate unemployment in standard equilibrium macroeconomic models. Because of its central importance, it seems sensible to look for sources of theoretical breakdown at the core of the Mortensen-Pissarides model. For this reason, we consider a logical generalization of the matching function that subjects it to exogenous multiplicative shifts that alter the allocative efficiency of labor markets.

We find the idea of cyclical matching efficiency plausible and intuitive. For example, consider the U.S. auto industry which shed over 50 percent of its workers during the 2008-09 recession. These separated workers are geographically distinct in that most of them reside in the industrial Midwest and the South. More importantly, they are also defined by their skills which are not likely to be the best match in an expanding sector such as health care. Similar observations can be made of the construction industry during this time. A reasonable measure of labor market mismatch would naturally rise under these circumstances, reducing matching efficiency and shifting the matching function. That is, the matching efficiency shock absorbs the inefficiencies created by cyclical variations in labor market mismatch, introducing the needed flexibility to the standard formulation.

The large economic contraction of 2008-09 and the subsequent weak recovery in the labor market motivated a number of studies trying to ascertain the cyclical importance of mismatch. For instance, Barnichon and Figura (2011a, 2011b) find that matching efficiency, as we model here, displays substantial variability over the business cycle and can play a significant role during recessions and might reflect the underlying labor market heterogeneities not captured by the aggregate matching function. Similarly Veracierto (2011), focusing on the last decade, finds that matching efficiency has been notably volatile with a downward drift since the beginning of the last recession. Sahin et. al. (2011) construct a measure of mismatch for the U.S. economy and argue that sectoral and occupational mismatch has increased since the recession. Although this evidence argues for procyclical matching efficiency, we do not take a position on its cyclical properties *a priori*. Instead, we will estimate this process using our model. Our estimation results indeed suggest that this shock represents a significant source of procyclical variation over the business cycle.

We also motivate time variation in the rate of job separation on the basis of empirical evidence. Although Shimer (2005b) argues that the job separation margin is not important for business cycle-frequency variation in unemployment (employment), there is considerable debate in the literature as to which margin–separation or job creation–is more important in accounting for employment fluctuations. For instance, Barnichon and Figura (2010), Elsby, Michaels, and Solon (2009), Fujita and Ramey (2009) and Tasci (2011) as well as earlier work by Darby, Haltiwanger, and Plant (1986), all suggest that separations play a non-trivial role over the business cycle. Once again, we do not take a position on a shock's cyclical properties *a priori*, but will rather estimate it along with the other two shocks. As discussed above, for the multiple-shock model to explain the data, job separations must be procyclical in contradiction to existing evidence. This finding sets the stage for further exploration of the matching models's mechanics in section 6.

3 The Model

In this section we construct a multiple-shock, discrete time version of the basic labor market search model. It contains three sources of exogenous variation: shocks to labor productivity, job separation, and matching efficiency. Although there are a number of differences between this model and the standard Mortensen-Pissarides framework, we will show that the simulation properties of a single-shock analogue model are virtually indistinguishable from the version used by Shimer (2005a) to establish the amplification puzzle.

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 and 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).

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 implying aggregate search costs equal to $\phi(1-N_t)$. Firms create job vacancies 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 of 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 determines the number of job matches formed in a given period $M(V_t, U_t)$ as an increasing and constant returns function M of job vacancies V_t and the number of job seekers U_t. A central tenet of the paper is that the standard matching function is overly restrictive by not allowing for changes in the degree of mismatch over the business cycle. In other words, the the quantities V_t and U_t are not a sufficient representation of heterogeneity-induced information problems and their fluctuations.

To allow for fluctuations in mismatch, we generalize the matching function to include a multiplicative shock term χ_t such that the number of matches formed in period t is given by

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

where $0 < \alpha < 1$ and χ_t is the period-t realization of an unobserved shock process. An increases in χ_t produces additional job matches given the numbers of searching workers and available positions. From a searching worker's perspective, an increase in χ_t raises the probability of being matched with a vacant position; from the perspective of a single firm, it improves its chances of filling a vacancy. So in the aggregate, upward and downward movements in χ_t signify improvements or deteriorations in the labor market's allocative efficiency.

As job matches form, others are dissolved. We assume that a fraction of existing matches σ_t dissolve each period according to an exogenous stochastic process. The net employment flow is hence defined as the difference between a period's gross employment inflow and gross employment outflow:

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

Note that two of the three shocks directly impact each stream of workers: the flow into employment by allocative efficiency χ_t, and the outflow by the separation rate σ_t.

The state of the economy in a given period (N_t, e_t) consists of the beginning-of-period employment level N_t and the random and exogenous state vector, $e_t = (Z_t, \chi_t, \sigma_t)$. We make the standard Markovian assumption that agents form expectations of future-period quantities using only current-state knowledge. Given that state, the socially efficient allocation of employment, vacancies, and consumption $\{N_{t+1}, V_t, C_t\}$ solves the following recursive 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

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

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

where $\upsilon\left(N_t, e_t\right)$ is the future-discounted social value of employment level N_t and the exogenous state e_t. Equation (6) is the economy's 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.

Finally, we assume that the exogenous state vector is governed by the stochastic process

$$e_{t+1} = Ae_t + \varepsilon_{t+1}, \quad \varepsilon_t \sim iid\mathrm{N}\left(0, \Omega\right) \tag{8}$$

where A is a 3×3 matrix of constants and $\mathrm{E}(\varepsilon\varepsilon') = \Omega$ is a 3×3 variance-covariance matrix. We further denote the three rows of A by $a_i = (a_{iz}, a_{i\chi}, a_{i\sigma})$, for $i = z$, χ, σ, respectively, and follow the same convention for Ω, i.e. $\omega_i = (\omega_{iz}, \omega_{i\chi}, \omega_{i\sigma})$, $i = z$, χ, σ. In what follows, we assume that the innovations are mutually uncorrelated so that Ω is diagonal, i.e. $\omega_{ij} = 0$, $i \neq j$.

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

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

equating the loss in welfare due to vacancy creation with its expected future social benefit. In equation (9), $\frac{1}{\chi M_V} = \alpha^{-1} \frac{V}{\chi M}$ gives the average duration of vacancies multiplied by the elasticity of vacancies in matching $\alpha = \frac{V M_V}{M}$ and thereby represents the utility loss associated with a marginal increase in vacancies. The expected gain of the marginal vacancy on the right-hand side of (9), derives from multiple sources. The expression $Z' + \phi + \frac{U'_N}{U'_C}$ represents the period-ahead net social benefit of an additional match formed currently: Z' is the output flowing from the match; ϕ represents the search cost no longer incurred by the worker in the match; and $\frac{U'_N}{U'_C}$ represents the consumption value of the leisure foregone by the newly matched worker. In the basic Mortensen-Pissarides setup this quantity is a constant whereas it varies endogenously in the Merz (1995) formulation.

The final term in braces represents the net future social benefit arising from the expected persistence of a job match. Considering that a 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 equals $\frac{\kappa M'_U}{M'_V}$.

Equations (6), (7) and (9) 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 the real wage determined as a Nash bargain between firms and households. The socially optimal allocation 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.[3] We maintain these assumptions throughout.

[3] Hosios (1990) determines the conditions under which the Pareto-optimum is supported as a decentralized market equilibrium in a static environment; Merz (1995) and Andolfatto (1996) do the same in dynamic general

4 The Data

Before proceeding to the estimation of our model, we briefly review the basic facts regarding the observed aggregate U.S. labor market measures, mainly employment (or unemployment) and job vacancies. In addition to these labor market variables, we use real output as our third observable. Because the model 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 the labor force or the age 16-and-over population. Although there are valid arguments in favor of both normalizations, we find that the choice does not affect our results, so we choose the labor force (employment plus unemployment) as our reference population.[4]

In the absence of a long time series on actual job vacancies, we follow standard practice and construct vacancies from the Conference Board's help-wanted advertising index.[5] Since this measure is based on print-based advertising, it is likely to underestimate the true number of vacancies for the latter part of the sample. To correct for this bias, we apply the method proposed by Barnichon (2010) to the data in the post-1995 period. The resulting vacancy series (V_t) is also expressed per member of the labor force.

Because our model abstracts from the capital accumulation decision, we must also choose between output and consumption as an output measure. In an earlier version of the paper, we chose to use real nonfarm business output over consumption and showed that the choice was immaterial to our conclusions.[6] With this in mind, we are going to use real output as our third observable and present the results for the consumption-as-output case in the Appendix.

The labor market variables, employment and vacancies, are available at the monthly frequency but real GDP, the natural choice for an output measure, is only available at a quarterly frequency. The ordinary solution to frequency mismatch is simply to time-average the monthly series and express everything at a quarterly frequency. We think that the labor market dy-

equilibrium settings. The market equilibrium in the current work closely follows those of Merz and Andolfatto.

[4] We use the unemployment rate as measured in the Current Population Survey (CPS) of the Bureau of Labor Statistics (BLS). The civilian labor force is also part of the CPS. Both series are downloaded from the *Haver Analytics Database*.

[5] We construct a vacancy series by multiplying two seasonally adjusted monthly series: the ratio of help-wanted advertising to unemployment compiled by the Conference Board (downloaded from *Haver Analytics*), and unemployment as measured by the CPS.

[6] See Beauchemin and Tasci (2011).

namics that underlie the fluctuations in N_t, and V_t, however, are better captured using the higher frequency monthly data to minimize time-aggregation biases.[7] For example, the average unemployment duration in the data is roughly one quarter, meaning that potentially important features of labor market dynamics are essentially washed out by the quarterly averages. On a more technical note, we prefer to calibrate the model at a monthly frequency to minimize the number of occurrences in which the job finding rate implied by the matching function strays from its theoretically consistent range between zeros and one in simulation. Hence, we favor monthly data for the estimation and calibration of our model, but to preserve comparability with other studies, we report moments at the quarterly frequency, both for the historical data and simulations. The choice to use monthly data requires us to use an inferred monthly measure of real output. We address this issue by using the monthly estimates of the real GDP constructed by Stock and Watson (2010).[8]

Table 1 summarizes the key business cycle features of the data on U_t, V_t, V_t/U_t, and Y_t. We include private nonfarm labor productivity as part of the data description for comparison purposes. Although it is not strictly consistent with the model implied measure, our earlier work (Beauchemin and Tasci, 2011) shows the behavior of the two detrended analogue series to be nearly identical.[9] To describe the business-cycle variation in these quantities, we follow standard practice and remove the low-frequency trend in all variables (at the quarterly frequency) implied by the Hodrick-Prescott filter, using a smoothing parameter of 10^5. We apply this procedure to remove movements in the aggregates induced by institutional and technological change in labor markets which are not associated with the business cycle. The key cyclical features of the U.S. data are summarized in Table 1.

[7] Calibrating similar models at a higher frequency is becoming a common practice in this literature, see for instance, Hagedorn and Manovskii (2007).

[8] Monthly GDP data is retrieved on November 22, 2011 from the following web address: http://www.princeton.edu/~mwatson/mgdp_gdi.html. See Stock and Watson (2010) for the details.

[9] The series is from the BLS' Productivity and Costs program and is downloaded from *Haver Analytics.*

Table 1: U.S. DATA (Quarterly, 1959:Q1-2010:Q2)					
	u	v	v/u	y	z
Standard Deviation	0.182	0.184	0.356	0.026	0.021
Autocorrelation	0.958	0.949	0.956	0.938	0.905
Cross Correlations					
u		-0.901	-0.975	-0.849	-0.383
v			0.975	0.776	0.378
v/u				0.833	0.389
y					0.764

From Table 1, we observe that employment, vacancies, and the vacancy-unemployment ratio are all strongly procyclical and persistent, while unemployment is strongly countercyclical and persistent. These data also reveal a distinct Beveridge curve with a contemporaneous correlation between vacancies and unemployment of -0.901. Note that unemployment and vacancies are nearly 10 times more volatile than labor productivity, and the volatility of the vacancy-unemployment ratio (market tightness) is extreme, with a standard deviation of 36 percent around its trend. Although these facts are mutually consistent with the qualitative predictions of the standard model, Table 1 also points out the model's quantitative shortcomings as put forth by Shimer (2005a). We will contrast these facts with the standard model's implications in the following section.

5 Simulating the Model

In this section, we describe our calibration approach and the maximum likelihood estimation of a subset of the parameters. As in Chari, et. al. (2007), we calibrate the preference and technology parameters using a combination of long-term data averages and micro-evidence, and subsequently, estimate the parameters for the stochastic process governing the exogenous state vector $e_t = (Z_t, \chi_t, \sigma_t)$ using maximum likelihood. With the estimates in hand, we simulate the model and describe its cyclical features.

5.1 Calibration and Estimation

With a large empirical literature to draw upon, we combine micro-evidence with long-run data averages to calibrate the steady state values of the exogenous shocks and the technology and preference parameters. We begin by targeting the steady state values of the labor market variables (N_t and U_t) to match the corresponding first moments of the data: $N = 0.942$, and $U = 0.058$. Because of the form of the matching function (3) the steady state level V is irrelevant given the one for U. We set α equal to 0.28 which is the value used by Shimer (2005a). Because this is at the low end of the estimates surveyed by Petrongolo and Pissarides (2001), the Appendix replicates our experiments under alternative settings of this parameter.

Next, we consider the two preference parameters, namely the subjective discount factor and the Frisch elasticity of the labor supply (β and γ). We choose $\beta = 0.9967$ consistent with a steady state risk-free real interest rate of 4 percent at the monthly frequency. We follow Merz's (1995) interpretation of the empirical literature and choose $\gamma = 1.25$ for the Frisch elasticity.

Given these values for β, γ, and α, along with the steady state target for N (or $1-U$), we are left with the steady state exogenous vector (Z, χ, σ) and the two parameters that determine the cost of search for workers and employers (ϕ and κ) to calibrate. Without loss of generality, we normalize the steady state of inferred aggregate output to one, $ZN = 1$, implying steady state labor productivity of $Z = 1/N = 1.06$. Unlike the model's other parameters, independent evidence regarding ϕ and κ is scarce to non-existent. We follow Andolfatto (1996) and assume that steady state recruiting expenditures and the steady state search costs for workers are at most one percent of output. For the steady state search costs for workers this implies $\phi = 0.173$. We then choose κ and χ so that the model generates steady state unemployment (defined above), while keeping the cost of recruiting expenditures below our one-percent target. Satisfying that dual objective requires setting $\kappa = 0.394$ and $\chi = 0.43$. Given these values, the steady state monthly job finding rate in the model is 29.78 percent, which is consistent with the observed average unemployment duration of 14.55 weeks in the data sample. Under these assumptions, the steady state value of consumption is $C = 0.98$. Finally, the steady state version of the equation-of-motion for employment (7) and our steady state values for χ and α imply the steady state job separation rate $\sigma = 0.018$, or 1.8 percent a month. Table

2 summarizes the calibration results. As part of our robustness checks, the Appendix present results that correspond to different values of γ and α.

Table 2: Calibrated Parameters

Parameter	Value	Source/Target
β	0.9967	4% real interest
α	0.28	Shimer (2005a)
γ	1.25	Merz (1995)
ϕ	0.1733	1% of output
κ	0.3941	1% of output
χ^{ss}	0.4314	u^{ss}
z^{ss}	1.0612	Avg. output = 1
σ^{ss}	0.0182	u^{ss} and u duration

We next turn to estimating the parameters of the exogenous shock process (8) represented by the nine equation coefficients contained in A and the three (nonnegative) diagonal elements of Ω; the off-diagonal elements of Ω are set to zero reflecting our belief that the innovations of the shocks are contemporaneously uncorrelated. The assumption also helps greatly in facilitating computation while sacrificing little in the way of description as the shocks themselves are permitted a rich correlation structure by the VAR(1) specification assumed in (8).

The maximum likelihood estimates are reported in Table 3.

Table 3: Maximum Likelihood Estimation Results

Z-equation			χ-equation			σ-equation		
a_{ZZ}	0.5686	(0.0342)	$a_{\chi Z}$	1.4190	(0.2122)	$a_{\sigma Z}$	1.4190	(0.2122)
$a_{Z\chi}$	0.0073	(0.0037)	$a_{\chi\chi}$	1.1164	(0.0084)	$a_{\sigma\chi}$	0.8842	(0.0428)
$a_{Z\sigma}$	−0.0063	(0.0042)	$a_{\chi\sigma}$	−0.3213	(0.0145)	$a_{\sigma\sigma}$	−0.0433	(0.0450)
ω_{ZZ}	0.0001	(0.0002)	$\omega_{\chi\chi}$	0.0122	(0.0034)	$\omega_{\sigma\sigma}$	0.0022	(0.0023)

$L = 6321.3$. Standard errors are in ().

With all parameter values of the multiple-shock model determined (and summarized in Tables 2 and 3), we can now turn to the model simulations to study the economy's properties.

5.2 The Benchmark Economy: Basic Properties

Before analyzing the multiple-shock search model, we wish to establish the correspondence between our discrete-time, centralized model economy and the continuous-time, decentralized version of the standard model used by Shimer (2005a). To do this, we simulate the model with constant job separation and matching efficiency, but allow labor productivity Z_t to vary stochastically as the only source of exogenous variation. Specifically, we set σ_t and χ_t to their steady state values for all t (given in Table 2) and assume that Z_t follows a first-order autoregressive process such that the first-order autocorrelation and the standard error of the innovation match the corresponding data moments. To preserve comparability with Shimer (2005a), we estimate the Z_t process using the BLS measure of output per worker in the non-farm business sector (summarized in Table 1)[10].

Our general solution algorithm is based on Christiano (2002) and relies on the log-linearized version of the first-order condition (9). We posit linear decision rules for log deviations of the endogenous variables V_t, N_{t+1}, and C_t around their respective steady states as a function of N_t and $e_t = (Z_t, \chi_t, \sigma_t)$. In the benchmark model the exogenous state consists of only Z_t.

Table 4 presents sample moments computed from 1000 simulations of the model economy where each simulation is 650 periods in length. To facilitate comparison with Table 1, each variable is detrended using the H-P filter with smoothing parameter 10^5. We summarize this table with three broad findings. First, vacancies and market tightness (v/u) are significantly procyclical while unemployment is countercyclical. Second, the Beveridge curve relationship is consistent with the benchmark model as shown by the negative correlation between unemployment and vacancies of -0.892. Finally, fluctuations in the labor market variables are substantially smaller than the underlying variation in productivity.

[10] The underlying monthly AR(1) process for Z_t has an autoregressive coefficient of 0.96 and an error error of 0.008.

Table 4: Simulations of Benchmark Economy					
	u	v	v/u	y	z
Standard Dev.	0.004	0.011	0.015	0.027	0.027
Autocorrelation	0.948	0.860	0.902	0.906	0.905
Cross Correlations					
u		−0.892	−0.938	−0.942	−0.941
v			0.994	0.992	0.992
v/u				1.000	1.000
y					1.000

This last observation provides the thrust of Shimer's (2005a) argument that the standard search model lacks the mechanisms that enable it to amplify realistically sized productivity shocks to produce the extent of variation in vacancies, unemployment, and market tightness observed in the data. The third rows of Table 1 and Table 4 confirm this point. We conclude that the model with only productivity shocks behaves similarly to the criticized search model even though we rely on a social planner's problem framed in discrete time. In what follows, we adhere to convention and refer to the discrepancy between the standard model and the data as the "amplification puzzle."

5.3 The Multiple-Shock Economy: Basic Properties

We now focus on the model where the exogenous state space contains the full set of shocks (Z_t, χ_t, σ_t) that follow the VAR(1) process estimated above. Having introduced two additional shocks to the model, we expect to resolve the amplification puzzle to some extent. To help gauge the contribution of the two additional shocks, we report the moments in a fashion similar to Tables 1 and 4. Table 5 presents the sample averages of moments from 1000 simulations of the model economy, where each simulation is 650 periods in length. Once again, we report the percentage deviations from trend.

Table 5: Simulations of multiple-shock Economy							
	u	v	v/u	y	z	χ	σ
Standard Dev.	0.067	0.059	0.119	0.010	0.008	0.224	0.194
Autocorrelation	0.610	0.634	0.638	0.390	0.329	0.639	0.610
Cross Correlations							
u		−0.784	−0.951	−0.567	−0.131	−0.933	−0.950
v			0.937	0.617	0.324	0.880	0.927
v/u				0.625	0.235	0.962	0.994
y					0.890	0.561	0.597
z						0.167	0.202
χ							0.932

The simulation results from the multiple-shock economy show significant improvements toward resolving the failure of the benchmark model. As expected, we observe substantially more volatility in all key variables, especially labor market aggregates $V_t\ /U_t$, V_t and U_t. In fact, the standard deviations of $V_t\ /U_t$, V_t and U_t relative to that of labor productivity are very close to the data counterparts, due in large measure to the very volatile behavior of the matching efficiency and job separation shocks. The cross correlations in Table 5 also reveal a negative comovement between unemployment and vacancies, consistent with the empirical Beveridge curve. Also, note that all shocks are procyclical. Procyclical labor productivity is, of course, to be expected, and the procyclical behavior of matching efficiency suits our intuition along with some recent evidence discuseed in section 2. Most researchers, however, would find it difficult to reconcile the procyclical job separation finding with existing empirical estimates of separation rates or gross job flows. Thus, introducing two additional and plausible sources of exogenous fluctuation partly resolves the amplification puzzle, but also produces questionable features for the implied worker flows.

We devote the next section to understand the reasons behind this result.

6 Accounting for Imperfection

It is no surprise that the multiple-shock approach produces better results in terms of the volatility of endogenous variables. Beyond that, the simulation results of the previous section provide more questions than answers. What are the reasons behind the apparent counterfactual implications? In this section we apply business cycle accounting techniques (Chari, et. al., 2007) to gain some traction on this question. The experiment is conducted in two steps. First, we compute the innovations of the shock process that would be obtained if the actual data-generating process were indeed the multiple-shock model. Because the model has been designed to contain three unobserved shocks to match the number of observed endogenous variables, we can back out a unique realization of shocks (Ingram, Kocherlakota, and Savin, 1994) that satisfy both theory and data. The second step involves feeding individual shock series into the model while holding others constant to isolate the potential sources of model incompleteness producing the counterfactual behavior.

6.1 Perfect-Fit Experiment

In consideration of our estimates of A and Ω presented in Table 3, and the linearization-based algorithm that we use to solve the model, solving for the unique time-series realizations of "perfect-fit" shocks is straightforward and only involves a simple inversion of the log-linearized model.[11] The perfect-fit shocks will naturally reflect the results of the Monte-carlo simulations of the previous section.

Figure 1 plots the implied perfect-fit shock time series for Z_t, χ_t, and σ_t, and Table 6 presents statistics that summarizes their business cycle characteristics. As before, all variables are expressed in terms of their log-deviations from trend. As we can see from the table, to ensure a perfect fit to the data, the standard deviation of both matching efficiency and job separation are required to be much larger than that of labor productivity, and both are required to be procyclical.

[11] See Beauchemin and Tasci (2011) for the details of this exercise.

Table 6: Required Shocks for a Perfect Fit			
	Z	χ	σ
Standard Deviation	0.0107	0.4516	0.3893
Autocorrelation	0.6239	0.9776	0.9672
Cross Correlations			
Z		0.3798	0.3383
χ			0.9784

To understand better the descriptive shortcomings of the model, we decompose the observed fluctuations in employment into the separate components due to each of the different shocks. To do this, we take the exogenous shock series that produced the perfect fit, and expose them to the model one (and later two) at a time. The remaining shocks are set equal to their steady state values in each period.

Figure 2 reports the results of the exercise. Each line represents the time-series behavior of employment implied by each of the single-shock models; actual employment behavior is also plotted for context. First, consider the model with labor productivity as the only exogenous shock. The corresponding employment behavior is nearly constant around zero, never displaying a fluctuation in excess of 0.2 percent in absolute value, implying that labor productivity shocks have little ability to generate realistic employment volatility. This result echoes the Shimer critique (2005a). Both the χ-only and σ-only cases generate larger employment volatility than the Z-only case, but observe that the employment series generated by the χ-only model is not only realistically volatile, it also mimics closely the procyclical pattern of the actual series. It is clear from these results, that matching efficiency is the most useful source of exogenous variation in the multiple-shock model to help understand the qualitative and quantitative problems of the Mortensen-Pissarides labor market search model.

Next, we further evaluate the model by running the three experiments that sequentially feed two of the three shocks into the model. The results of this exercise are presented in Figure 3. First consider the experiment which exposes the model to only the shock series for χ_t and σ_t that we backed out from the perfect-fit experiment (i.e. exclude Z_t). In this case, the implied behavior of employment is virtually indistinguishable from actual employment behavior–a convincing restatement of the result in the previous experiment in which employment showed virtually no response to the labor productivity shock alone. The remaining two experiments exclude χ_t and σ_t in turn, but only the latter generates the appropriate cyclical employment response. In other words, using only the labor productivity and allocative efficiency shocks allows us to produce employment behavior nearly identical to that from the χ-only shock in the previous experiment, lending more support for our conclusion that variation in matching efficiency is critical to understanding labor market dynamics.

The perfect-fit exercise has so far showed us how the shocks must behave if we take our model to be the true data-generating process. There is obviously nothing surprising with the implied series on labor productivity Z_t as it has measured analogues that can mimic its behavior closely. With respect to matching efficiency, we were mostly agnostic about its true nature but with a bias toward procyclical behavior based on intuition backed by some recent empirical work. Thus, we could accept our finding, but perhaps with the magnitude of the shock required. Nevertheless, the implied job separation series poses a significant challenge. It is impossible to reconcile a procyclical job separation shock with the existing evidence[12]. Moreover, our decomposition suggests that this component accounts for a somewhat significant fraction of observed employment fluctuations. Since we cast this experiment as a diagnostic procedure, we need an answer to the following question: What are the properties of the multiple-shock search model that require it to produce a procyclical and volatile job separation rate to account for U.S. employment fluctuations? A satisfactory answer to this question first requires an investigation into the mechanics of the standard labor market search model.

6.2 Search Model Mechanics

Motivated by largely observed persistent and procyclical movements of labor productivity Z_t, we make use of the model's efficiency conditions (6), (7), and (9) to trace out the labor market dynamics of the search model in response to a sudden and persistent increase in labor productivity, holding constant matching efficiency χ_t and the rate of job separation σ_t.

Consider first the effects of an innovation to labor productivity. By signaling greater future

[12] In addition to the evidence on worker flows discussed in Section 2, see for instance, Blanchard and Diamond (1990), Davis and Haltiwanger (1992), Davis, Haltiwanger, and Schuh (1996) that also focus on job flows.

productivity–as captured by the term Z' in the intertemporal efficiency condition (9)–firms respond by posting additional vacancies to reap the productivity benefits of filled positions, immediately increasing the vacancy-unemployment ratio. Subsequently, new matches form increasing employment and reducing unemployment, reinforcing the initial rise in the vacancy-unemployment ratio.

The productivity innovation also sets in motion forces that oppose the increasing vacancy-unemployment ratio. To see this, first note that the resource constraint (6) translates the anticipated increase in productivity and employment into higher future consumption by enhancing the output flow.[13] The increases in employment and consumption subsequently reduce the representative worker's marginal willingness to substitute non-market activities for consumption, i.e., $\frac{U'_N}{U'_C}$ decreases in equation (9). This offsets, to some extent, an individual firm's vacancy creation motive and the subsequent increase in employment. Furthermore, the draining of the unemployment pool persists and offsets some of the future benefits of currently high productivity by frustrating future hiring efforts through the term $-\frac{\kappa M'_U}{M'_V}$ representing the additional future recruiting costs exacted by the depleted stock of searching workers (right-hand side of (9)). 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, display extremely large procyclical variation in this ratio, which casts doubt on the model's ability to produce the required cyclical variation in response to realistically sized shocks to labor productivity.

By allowing both matching efficiency and the job separation rate to vary over the business cycle, the preceding diagnostic procedure responds to this tension by equating the observed vacancy-unemployment ratio with the socially optimal one in each period. The highly variable and procyclical matching efficiency shock χ_t implied by this exercise (Table 6 and Figure 1) effectively increases the expected gains of vacancy creation in response to exogenous increases 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

[13] Individually and in sum, the other terms of the resource constraint having little weight here: the sum of search and vacancy-creation costs $\phi(1-N_t)+\kappa V_t$ is small, and the increase in vacancy-creation costs κV_t counteracts the reduction in search costs, $\phi(1-N_t)$.

with falling unemployment gives an additional upward push to the vacancy-unemployment ratio, moving the economy along the Beveridge curve in accordance with the data. However, given that the aggregate employment (or unemployment) data reveal relatively small period-to-period changes, the model requires a much larger employment outflow to restock the unemployment pool depleted by the enhanced matching efficiency. In the multiple-shock model, this element can only be provided by the required procyclical (and apparently counterfactual) rate of job separation σ_t (Table 6 and Figure 1). One will recall Figures 2 and 3 which indicate that movements in χ_t need an offsetting movements in σ_t to generate empirically consistent employment fluctuations.

6.3 A Resolution: Procyclical Reallocation

At this point we could accept the results of our experiment with a claim that matching efficiency and job separation are both strongly procyclical. As we have already stated, however, sharply procyclical job separation is at odds with existing data. Instead, we look for economic meaning in the results to identify likely sources of model misspecification and propose potentially productive modifications to the standard labor market search framework.

We proceed by ascertaining the reasons behind the procyclical behavior of both matching efficiency and job separation drawing upon our discussion in the previous subsection. There we traced out the first-stage response of the economy to a positive labor productivity and summarize it here as follows: vacancies rise as firms anticipate future productivity gains, unemployed workers are matched in new positions, and as a consequence reduces the pool of available workers. Note that the model mechanics have pushed the vacancy-unemployment ratio higher creating the appropriate procyclical pattern, but not with the amount of force required to produce the observed volatility in the vacancy-unemployment ratio. The smaller pool of unemployed workers sets up the second-stage of the overall response as vacancy creation is made less attractive, dampening the overall rise in the ratio.

The role of procyclical matching efficiency in amplifying the rise in the vacancy-unemployment ratio is now apparent, as it raises the probability of matching a searching worker to a vacant position thereby creating further incentive for firms to post vacancies. But this will only help reconcile the model with the data if the subsequent response for firms to pull back on vacancy creation due to a diminished pool job candidates can be thwarted, or at least mitigated. Any mechanism that expands or replenishes the job-candidate pool will help in this regard. The most direct and straightforward extensions to the basic model that we can conceive is to expand the pool of searching workers either by allowing a labor force participation decision or by permitting job-to-job transitions. In the case of the former, a vacancy that is filled by a person (authentically) designated as out-of-the-labor-force, leaves unemployment unchanged and preserves the vacancy-creation incentive. The same is accomplished with a job-to-job transition in a model that permits on the job search. In that case, a higher vacancy-unemployment ratio is sustained by additional procyclical churn. Because the distinction between unemployment and nonparticipation is a vague one, we fine the second route more appealing.

Our results and subsequent interpretation create a nice point of comparison to some of the recent literature. Nagypal (2004) and Shimer (2005b) argue that job-to-job transitions are crucial for cyclical worker reallocation. Exploiting dependent interviewing methods introduced in the CPS in 1994, Fallick and Fleischman (2004) find that these flows are large: on average 2.6% of employed workers change employers each month. Moreover, job-to-job transitions are procyclical. This particular flow cannot be analyzed by standard search models. Thus, on-the-job search provides a natural research avenue to pursue. Krause and Lubik (2006), Nagypal (2006), and Tasci (2007) are examples of this approach. Recently, Ramey (2008) also argues that endogenous separations accompanied by on-the-job search is likely to improve overall model fit. In Nagypal (2006), information frictions generate a bias for firms to hire employed workers, reducing the dampening second-stage effect. Alternatively, in Tasci (2007), underlying match heterogeneity resulting from symmetric incomplete information about the quality of the job-worker match implies a measure of workers employed in relatively low quality matches during expansions. These workers have the incentive to accept better quality matches and provide the additional incentive for firms to post vacancies.

Recent studies have attributed the amplification puzzle to different characteristics of the standard labor market search model with only a productivity shock. Shimer (2005a) and Hall (2005) suggest that the underlying wage determination mechanism is the reason for the lack of amplification in these models. Hall (2004, 2005), Shimer (2004), and Kennan (2010) build on this presumption and introduce wage rigidity either exogenously or through an endogenous mechanism, such as asymmetric information. Several studies also aim to provide a mechanism that can amplify the effects of business cycles on unemployment and vacancies. Hagedorn and Manovskii (2007) use a high value of nonmarket activity to generate amplification, which also implies an excessive unemployment response to a slight increase in unemployment compensation (Costain and Reiter, 2008; Hornstein, Krusell, and Violante, 2006). Silva and Toledo's (2009) result depends on a particular constellation of parameter values for separation and hiring and training costs that is hard to quantify empirically.

We note in closing that our focus on the centralized planning problem is not likely to alter any of our conclusions. As argued extensively by Mortensen and Nagypal (2007), wage rigidity *per se* is not the reason for amplification. For instance, even in a case where the workers' lack of bargaining strength leads to constant wages equal to the reservation wage (i.e., the value of leisure), the variability of labor market variables relative to productivity is an order of magnitude smaller than found in the data (Mortensen and Nagypal, 2007). Moreover, Pissarides (2009) argues that the empirical evidence in favor of wage rigidity over the cycle is not valid for newly created matches, which is the important margin for job creation in the standard model. From this we conclude that our social planner's formulation of the economy, which implicitly ignores wage determination, is not crucial for understanding the amplification puzzle.

7 Conclusion

We have extended a basic discrete-time version of the Mortensen-Pissarides model of labor market search to include multiple and mutually correlated sources of exogenous variation. We use the extended model to investigate the basic matching model's well-known tendency to underpredict the volatility of key labor market variables. The shock process comprises labor productivity, job separation, and matching efficiency and is estimated using data on unemployment, vacancies and real output for the U.S. economy. Although our model generates more volatility in labor market variables while preserving the Beveridge curve relationship, it has counterfactual implications for the job separation rate.

We exploit the degrees of freedom facilitated by the multiple-shock structure of our model to uncover the mechanics, or lack thereof, that generate the empirically implausible implications.

This leads us to our second exercise, which forces the model to be the data-generating process, allowing us to uncover the realizations of the shocks necessary to replicate the data. We show that the standard labor market search model requires significantly procyclical and volatile matching efficiency and job separations to simultaneously account for high procyclical variations in labor market tightness as well as the relatively small net employment change in the data. In this sense, the standard model is more fundamentally flawed than its inability to amplify shocks would suggest.

We conclude that the model lacks mechanisms to generate procyclical matching efficiency and labor force reallocation. The conclusion points us in the direction of models that expand the pool of searching workers, particularly those that allow job-to-job transitions as a productive first step in amending the standard model. We also show that variation in job separations and matching efficiency account for most of the employment fluctuations, suggesting that cyclical mismatch and endogenous separations may also be productive features of an improved model. Our hope is to stimulate further research into the nature of our findings and to generate even richer theoretical structures that will eventually give us a more thorough picture of aggregate labor market fluctuations.

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Appendix: Robustness

In this section, we check whether our findings are robust to different values for the elasticity of the matching function and the elasticity of the labor supply (α and γ). We also investigate the sensitivity of results to how the model variable C maps into the data.

Different Elasticities

Recall that we calibrated γ to be 1.25 based on Merz (1995). Since this parameter determines the response of the household labor supply to changes in productivity, it is important to know whether our results are sensitive to this choice. Similarly, we change the parameter value governing the elasticity of matching and check whether it fundamentally alters our conclusions. We present the key statistics from our robustness check in Table 7. These statistics include standard deviations of unemployment, vacancies, and vacancy-unemployment ratio and their correlations to the productivity shocks.

Our alternatives for γ are 2 and 0.5. Simulating the multiple-shock economy with these parameter values changes virtually nothing. The model continues to generate more volatility in labor market variables than the benchmark single-shock economy while preserving the negative comovement between unemployment and vacancies. Moreover, the counterfactual cyclical implications remain in place with procyclical job separations. When we repeat our perfect-fit experiment, the model continues to require procyclical job separation and allocative efficiency shocks.

Since $\alpha = 0.28$ lies at the lower end of the matching function estimates that Petrongolo and Pissarides (2001) provide, we consider higher values. This might be important, given that α also determines the share of the match surplus extracted by workers in the decentralized analogue economy. Increasing the value of α from 0.28 to 0.4 and 0.5 virtually does little to our results. As the share of firms increase, vacancy-creation becomes more sensitive to the underlying changes in the value of a match, which manifests as heightened variation in vacancies and market tightness. However, the shocks required for a perfect fit continue to exhibit procyclical matching efficiency and job separation. We conclude that our results remain in place for reasonably different values of the Frisch elasticity of labor supply and the elasticity of matching function.

Table 7:	*Robustness Checks for Various α and γ and different C^**					
	$\alpha = 0.4$	$\alpha = 0.5$	*$\alpha = 0.28$*	$\alpha = 0.28$	$\alpha = 0.28$	$\alpha = 0.28$
	$\gamma = 1.25$	$\gamma = 1.25$	*$\gamma = 1.25$*	$\gamma = 0.5$	$\gamma = 2$	$\gamma = 1.25$
std(u)	0.067	0.068	*0.067*	0.065	0.067	0.064
std(v)	0.060	0.062	*0.059*	0.058	0.059	0.058
std(v/u)	0.120	0.123	*0.119*	0.117	0.119	0.117
corr(u, v)	−0.796	−0.806	*−0.784*	−0.774	−0.780	−0.812
corr(χ, y)	0.553	0.551	*0.561*	0.551	0.558	0.442
corr(σ, y)	0.591	0.589	*0.597*	0.591	0.598	0.481

∗Last Column uses real PCE data instead of real output. Benchmark calibration uses $\alpha = 0.28$ and $\gamma = 1.25$ (fourth column).

Using Consumption rather than Output

As is typical in the labor market search literature, our model abstracts from capital accumulation. In our case, this means that the resource constraint (nearly) implies that consumption equals output. The choice of one over the other is mostly arbitrary, with arguments in favor of each. For the results presented so far, we have used real output. In addition to these, we ran all of our experiments using real personal consumption expenditures to measure C instead of output to gauge the robustness of our findings.[14] We briefly discuss the results here.

It is well known that consumption is smoother than output over the business cycle. Using real output could overestimate fluctuations in the marginal rate of substitution $\frac{U'_N}{U'_C}$ and dampen the incentive to create vacancies over the business cycle. So it is reasonable to think that using a smoother proxy for C in the context of the model might change our main results. It turns out that it does not. All labor market variables are as volatile as in the benchmark calibration where we estimated the exogenous processes with the output data. One distinct difference is degree of comovement between matching efficiency and output on the one hand, and separation and output, on the other. Both matching efficiency and the separation rate become less procyclical than when we use output data. Moreover, the perfect fit exercise implies that the exogenous

[14] We use a chain-weighted aggregate of nondurables and services consumption. The constituent parts are published monthly by the Bureau of Economic Analysis (download from *Haver Analytics)*.

state variables are less volatile and slightly less procyclical–a direct consequence of consumption being smooth relative to output. in sum, our qualitative results are robust to using consumption data to the measure model variable C.

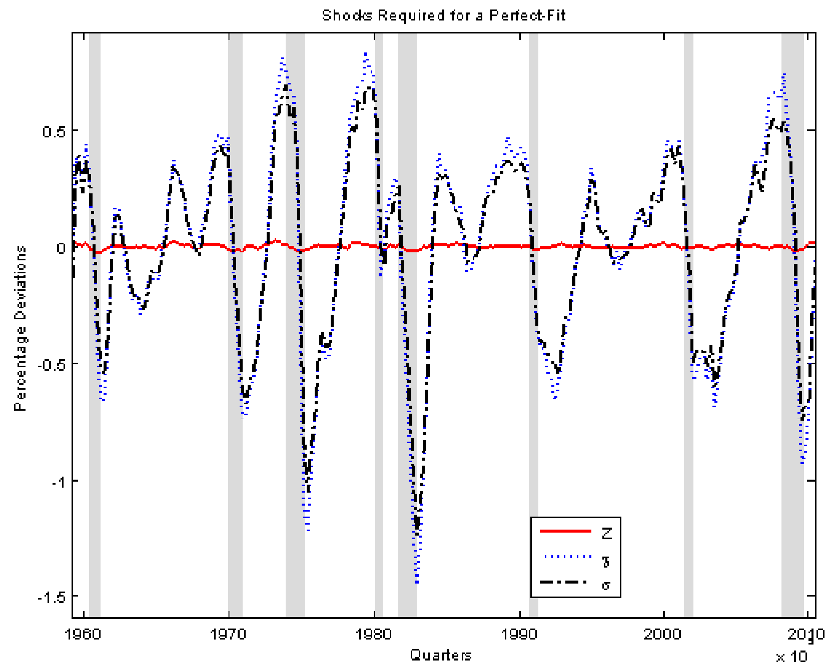

Figure 1: Shocks required for the perfect fit. Shaded areas indicate NBER recessions.

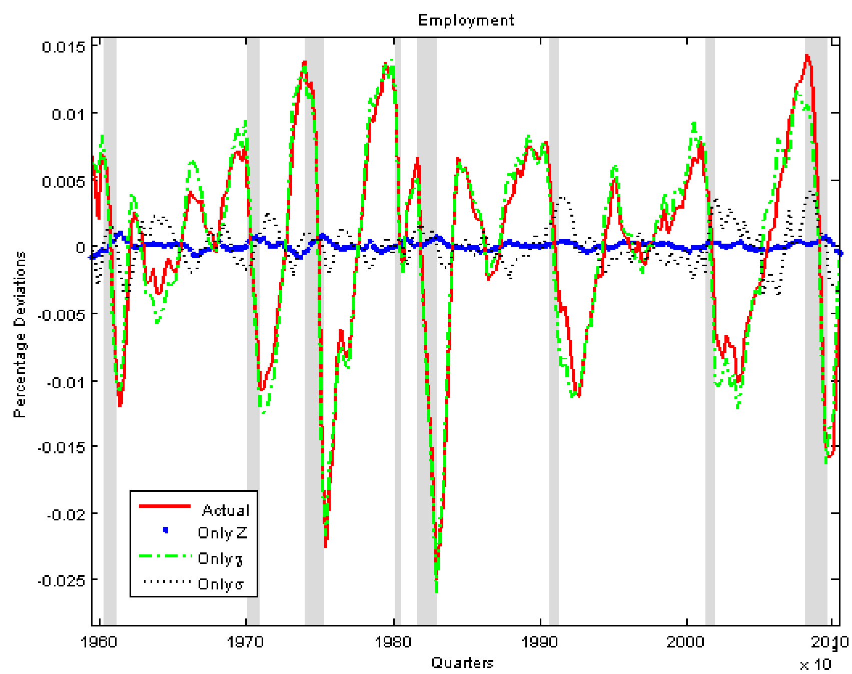

Figure 2: Contribution of each shock to employment fluctuations. Shaded areas indicate NBER recessions.

Figure 3: Contribution of pairs of shocks to employment fluctuations. Shaded areas indicate NBER recessions.