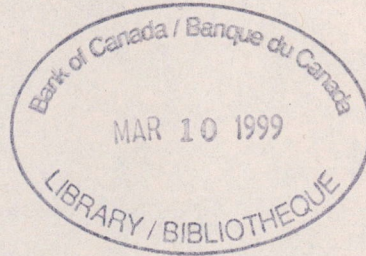


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Dynamic Employment and Hours Effects of
Government Spending Shocks

by
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**Dynamic Employment and Hours Effects of
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The views expressed in this paper are those of the author. No responsibility for them should be attributed to the Bank of Canada.

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Abstract

In this paper, we analyze the dynamic behaviour of employment and hours worked per worker in a stochastic general equilibrium model with a matching mechanism between vacancies and unemployed workers. The model is estimated for the U.S. using the Generalized Methods of Moments (GMM) estimation technique. An increase in government spending raises hours worked per worker, and crowds out private consumption due to a negative wealth effect. On the path converging towards the steady state, private consumption is below its long run average and increases, which implies that the interest rate is above its long run average and declines. The interest rate effect dominates the pure economic rent effect on the capital value of a hired worker to the firm, causing a reduction of job openings and consequently a decrease in employment. These results are contrasted with the predictions of a version of the Burnside, Eichenbaum and Rebelo's (1993) labor hoarding model.

Résumé

Les auteurs de l'étude analysent le comportement dynamique de l'emploi et du nombre d'heures travaillées par travailleur dans le cadre d'un modèle stochastique d'équilibre général doté d'un mécanisme d'appariement des postes vacants et des chômeurs. Le modèle est estimé pour les États-Unis à l'aide de la méthode des moments généralisés. Une hausse des dépenses publiques entraîne une augmentation du nombre d'heures travaillées par travailleur et provoque l'éviction d'une partie de la consommation privée par le jeu d'un effet de richesse négatif. Durant le processus d'ajustement vers le régime permanent, la consommation privée se situe sous sa moyenne à long terme et augmente graduellement, ce qui implique que le taux d'intérêt est supérieur à sa moyenne à long terme et baisse progressivement. L'effet du taux d'intérêt l'emporte sur celui de la rente économique pure dans la détermination de la valeur en capital d'un travailleur pour l'entreprise, d'où une réduction du nombre de postes disponibles et une diminution consécutive de l'emploi. Les auteurs comparent ces résultats aux prévisions d'une version du modèle de thésaurisation de la main-d'oeuvre de Burnside, Eichenbaum et Rebelo (1993).

1 Introduction

An important objective of fiscal policies is to influence the behavior of aggregate unemployment over the business cycle. Understanding the effects of fiscal policies, such as government spending on employment, is empirically and theoretically critical.

In the literature, the effects of government spending on total hours worked have been analyzed in Aiyagari, Christiano and Eichenbaum (1992), Christiano and Eichenbaum (1992), Burnside, Eichenbaum and Rebelo (1993), Burnside and Eichenbaum (1996), Baxter and King (1993), and Campbell (1994). However, a demand shock can change both the labor intensive margin, the number of hours worked, and the labor extensive margin, the number of employees of a firm. The total hours, as a product of the hours worked per worker and the number of employees, cannot alone provide information about the changes in the two margins. If we want to examine the behavior of unemployment after an aggregate demand shock, a decomposition of total hours worked is necessary.

This paper intends to accomplish two tasks. First, we will investigate the historical facts about the impact of a temporary government spending shock on employment, hours per worker and output based on the U.S. data. Second, we will develop a theoretical search model that can generate impulse responses similar to those of the empirical studies, especially the responses of the two labor market margins, and we will examine the model predictions on the relative effects of transitory versus persistent government shocks on the number of employees and hours worked per worker.¹ These results are compared with a reinterpreted version of Burnside, Eichenbaum and Rebelo (1993) (BER) model. The BER model does well in replicating the impulse responses of total output and total hours worked, yet does

¹Following Aiyagari, Christiano and Eichenbaum (1992), we call a shock with zero persistence a transitory shock, and those with positive persistence persistent shocks.

poorly in capturing the different responses of the two margins.

In the first part of this paper, we examine the effects of government consumption on the labor market of the U.S. economy in the postwar period. The responses of multivariate vector autoregression (VAR) models show that a temporary government spending shock increases total hours worked and output. However, when total hours worked are decomposed into the number of employees and hours worked per worker, the effects are quite different. The shock increases hours worked per worker but reduces employment. Furthermore, the hours worked per worker responds to the shock more quickly than employment. The change in employment, on the other hand, is more persistent than the change in hours worked per worker.²

In the second part of the paper, we consider a theoretical model based on recent advances in general equilibrium theories whereby employment is determined through a mechanism which matches unemployed workers and vacancies. Pissarides (1990) incorporates this matching mechanism in a balanced growth model. Andolfatto (1996) and Merz (1995) consider a stochastic real business cycle growth model with matching and compare the model's responses to technology shocks with a standard RBC model. In contrast to RBC models, in a search model the allocation of labor is determined by a matching mechanism. The inflow of workers into employment is the outcome of successful matching between job openings and unemployed workers. A firm creates vacancies at some cost and a hired worker brings some economic rent to the firm. The firm equalizes the cost of each job opening to the expected benefit of the opening in equilibrium. One implication of this model is that vacancies and unemployed workers exist simultaneously.³

²Karras (1993) also observes negative employment effects of government spending in the following countries: Australia, Belgium, Canada, Denmark, Finland, Japan, Korea and the Phillipines.

³For theoretical analyses of vacancies, see Pissarides (1985) and Blanchard and Diamond (1989). For empirical analysis at an aggregate level, see Abraham (1987). For empirical analysis on the magnitude and

The parameters in our model are estimated by the Generalized Method of Moments (GMM) estimation technique. The near steady state dynamics are obtained by using the log linear approximation method of King, Plosser and Rebelo (1990).

There are two main findings from our model. First, the parameterized model generates similar responses of both employment and hours worked per worker to a shock in government spending to those of VAR models. Second, numerical experiments with different degrees of persistence of government spending shocks show that a transitory government spending shock lowers employment, but a persistent government spending shock may decrease or increase employment depending on the degree of persistence of the shock. While the BER model generates similar impulse response for total hours, it does not capture the different responses of hours worked per worker and employment. Both our model and the BER model predict that a persistent shock has a larger effect on total hours and output than a transitory one. This is mainly due to the larger wealth effect on labor supply from a more persistent shock, echoing the argument of Aiyagari, Christiano and Eichenbaum (1992).

Concerning the output effect of the shock, three elements need to be considered: the capital stock; hours worked per worker; and the number of employees. Hours worked per worker increase after a shock in government consumption. The capital stock and the number of employees may increase or decrease depending upon the persistence of the shock. Although the capital stock and the number of employees may decrease, the positive hours effect dominates the negative effect on output so that output increases. The effect of government expenditure on total hours worked in the BER model is determined through intertemporal substitution. By assuming leisure is a superior good, a temporary shock to government spending decreases household consumption and leisure due to a negative wealth effect. Thus total hours worked

determinants of job vacancy rates in U.S. firms, see Holzer (1994).

and output both increase.

In our model, as in the BER model, the effect of government spending on hours worked per worker is determined through intertemporal substitution. However, the shock affects employment through a matching mechanism between unemployed workers and vacancies. Assuming exogenous separations of workers from employment, the job creation decision is determined by the capital value of a hired worker to the firm. A temporary shock in government spending has two effects on the capital value of a hired worker: a negative interest rate effect and a pure economic rent effect. The shock leads to an increase in the interest rate because only a higher interest rate will clear the goods market given an increase in aggregate demand. At the same time, higher interest rates lower the expected capital value of a hired worker to the firm. A higher pure economic rent in each period that a hired worker brings to the firm causes an increase of the capital value of a hired worker to the firm. Thus the overall effect of a shock on the capital value of a hired worker depends on the relative magnitudes of these two opposite forces. In the BER model, given a government consumption shock, the only contemporaneous labor margin that can be adjusted is hours worked per worker and it increases due to a negative wealth effect. In the following periods, employment would be increased and hours worked per worker would return to its steady state value. This is because increasing employment reduces an agent's expected utility less than increasing hours worked per worker (utility is linear in employment and convex in hours worked per worker).

The plan of this paper is as follows. Section 2 reports the empirical results from multivariate VAR models. In section 3, a theoretical model with a matching mechanism is set up and equilibrium conditions are derived. Section 4 discusses the parameter estimation procedure, the GMM technique. Section 5 contains a discussion of the parameter estimates

and comparisons of the search model, the BER model and the empirical VAR models. In Section 6, some conclusions are drawn.

2 An Empirical Analysis of the Effects of Government Spending Shocks

This section investigates the effects of government spending on the labor market, the interest rate and output in the postwar U.S. economy based on the use of VAR models. The data used in this analysis are quarterly seasonally adjusted time series for the sample period 1948:1 – 1993:4. National account variables are in 1987 dollars. (More details are given in Appendix 1.)

The VAR model is specified as

$$Z_t = A_0 + \sum_{j=1}^q A_j Z_{t-j} + u_t.$$

The disturbance vector, u_t , is assumed to be serially uncorrelated and to have variance-covariance matrix V . Furthermore, u_t is assumed to be related to the underlying shocks, ϵ_t , by $u_t = C\epsilon_t$ where C is a lower triangular matrix and ϵ_t has covariance matrix equal to the identity matrix. $V = CC'$. The orthogonality conditions on ϵ_t correspond to imposing a particular causal structure on the variables involved in the model. For example, the k^{th} element in Z_t is determined by Z_{t-j} for $j = 1, \dots, q$ and Z_{it} for $i = 1, \dots, k - 1$ and $k > 1$. q is set to 4.

In the VAR models, two measures of government spending are considered, government purchases of goods and services, and federal defense spending. The reasons to consider military spending are that it is usually regarded as an exogenous component in government spending, and the effect of military spending on employment is a matter of considerable importance.

Besides the labor market variables, total hours, employment and hours worked per worker, we also consider the real interest rate and output which are closely related to labor market activity. Government consumption shocks will affect aggregate demand, which in turn will lead to changes in labor demand decisions by firms. In the first VAR model, the total hours variable is included, and the second model includes the number of employees and the number of hours each employee works.

Denote the following variables:

GC = the log of government purchases of goods and services;

GFD = the log of federal defense spending;

NLF = the log of employee hours in non-agricultural establishments;

NF = the log of the number of civilians employed in non-agricultural industries;

LF = the log of hours worked per worker in non-agricultural industries;

$GDPC$ = the log of GDP;

RR = the real interest rate, calculated from 91-day T-bill yields and the GDP deflator.⁴

2.1 Total Hours Worked

To examine the effect of a government spending shock on total hours worked, we examine two alternative specifications of Z ,

$$Z = [GC \ RR \ GDPC \ NLF]',$$

and

$$Z = [GFD \ RR \ GDPC \ NLF]'$$

⁴According to the augmented Dickey-Fuller test statistics, RR is stationary and the other variables are nonstationary I(1) processes. As suggested in Doan (1992), p.8-3, all variables except RR are in logarithms and no time trend is included in our VAR estimations.

The impulse responses of the VAR models are plotted in Figure 1. Solid lines represent the point estimates, while dashed lines denote plus and minus two standard deviation bands.⁵

The graphs of the impulse responses for the two measures of government spending show that a positive innovation in government spending increases output and total hours worked. The interest rate declines in the first period and then starts increasing. However, the changes of neither total hours worked nor interest rates are statistically significant within two standard deviations. The responses to different spending shocks are qualitatively similar. These responses are consistent with the theoretical results of Aiyagari, Christiano and Eichenbaum (1992).

2.2 Employment and Hours Worked per Worker

In this section, total hours worked are decomposed into the number of employees (NF) and the hours worked per worker (LF). Two specifications of Z are considered,

$$Z = [GC \ RR \ GDPC \ LF \ NF]',$$

and

$$Z = [GFD \ RR \ GDPC \ LF \ NF]'$$

The impulse response functions of VAR models are plotted in Figure 2. The responses of each variable to the shocks of different measures of government spending are qualitatively similar. Employment and hours worked per worker respond differently to a shock in government spending. Hours worked per worker respond to the shock quickly and the changes are statistically significant for the first several quarters under both measures of government

⁵These estimates are computed using the Monte Carlo method described in Doan (1992; example 10.1), using 500 draws from the estimated asymptotic distribution of the VAR coefficients and the covariance matrix of the innovations, u_t .

expenditures. The time path increases for about 6 quarters and then declines. Employment responds slowly but the changes are more persistent. After an increase in government spending, employment decreases in the first two quarters, increases in the second half of the third quarter, and then decreases again, but the changes are not statistically significant though the decreases after one year are almost significant. The decrease in employment to an innovation in military spending is monotone and close to statistically significant after two years.

These results are robust to two kinds of perturbations. One is changing the ordering of the variables in Z . The experiments show that the responses of each variable are very similar with different positions of government spending in the ordering. Second, the results are qualitatively similar for a different measure of hours worked, that is, data from a household survey. The responses using household survey data show a larger decrease in employment and a smaller increase in hours worked per worker than those from establishment data.

Negative employment effects of government spending shocks are observed in some other countries according to Karras (1993). Karras (1993) considers the effect of government spending on employment and output. The results show that a transitory increase in government spending lowers employment in eight of eighteen countries in the sample. A persistent increase in government spending lowers employment in eight countries.⁶ The paper also finds that the multipliers of transitory changes in government spending are generally small: for a representative country, a one per cent transitory increase raises output by only 0.1 per cent.

The employment effect of military spending of the VAR model is consistent with the findings of some other empirical work. Dunne (1991) provides an analysis of military spending

⁶The countries in the sample are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Korea, Netherland, New Zealand, Philippines, Spain, Sweden, and United Kingdom.

and unemployment for 14 OECD countries. The results suggest that fears that cuts in military spending will lead to an increase in unemployment are unjustified, and he shows that disarmament presents an economic opportunity rather than a problem. Abell (1990) brings U.S. time series evidence to bear on the relationship of defense spending and unemployment rates. The analysis indicates that the increase in defense spending during the 1970s was associated with the improvement in the overall unemployment rate. However, during the 1980s, such increases were associated with a worsening of the unemployment rate.

Summarizing the results of our VAR analysis, we find that: total hours worked responds positively to increases in government spending; However, if total hours worked is decomposed into employment and hours worked per worker, we see that a spending increase leads to different responses in these two components. More specifically, hours worked per worker responds to the shock more quickly than employment and increases in the first several periods and then decreases. On the other hand, employment stays at the same level in the first several periods and then gradually decreases. Finally, the changes in employment are more persistent than hours worked per worker.

3 A Stochastic General Equilibrium Model with a Matching Mechanism

The model economy includes households, firms and government. The household's employment status is determined by a lottery mechanism. It is assumed that there is an insurance market in the economy such that agents can insure themselves fully against idiosyncratic risks. This assumption makes households ex-ante identical and simplifies the analysis. Firms create vacancies in the labor market and some vacancies are filled through a matching mechanism. In each period, some existing jobs are destroyed exogenously. The difference between

the filled vacancies and the job separations is the increment in employment.

3.1 Households

The economy has a large number of infinitely lived households. The population size is normalized to 1. Each household has capital good a_t which can be rented to a firm and a unit of time which can be divided into working hours h_t and leisure $1 - h_t$. The household derives utility from consumption goods, c_t , and leisure, $1 - h_t$. The momentary utility function at time t is given by

$$U(c_t) + \xi H(1 - h_t),$$

where ξ is a constant parameter and U and H are assumed to be increasing, concave and twice continuously differentiable.

A household's employment status is determined in each period via a lottery mechanism similar to the one described by Hansen (1985) and Rogerson (1988). Assume there exists a competitive and costless insurance market. At the beginning of each period, households may purchase b_t units of insurance at a price p_t per unit, where b_t is the quantity of the consumption good which is delivered to the household contingent on unemployment during that period.

In period t , there are n_t available jobs to be rationed among the population. For each individual, the probability of being employed equals n_t . Households lend their capital stock at u_t , and provide their labor, h_t , if they are employed.

The budget constraints of agents are contingent on their employment status. In the following constraints, subscript 1 represents the status of being employed, and 2 represents the status of being unemployed. Denote δ_k as the depreciation rate of capital stock, w_t as the wage rate, u_t as the rental rate of capital stock, and a_t as the quantity of the capital asset. If

the agent is employed, his income is composed of wage income ($w_t h_t$), rent ($u_t a_{1,t}$), dividend payment (π_t) and transfer payment from government (T_t); the income is allocated among consumption ($c_{1,t}$), investment ($a_{1,t+1} - (1 - \delta_k)a_{1,t}$), and payment of insurance premium ($p_t b_t$). Thus the budget constraint for an employed agent is

$$c_{1,t} + a_{1,t+1} - (1 - \delta_k)a_{1,t} + p_t b_t \leq w_t h_t + u_t a_{1,t} + \pi_t + T_t.$$

Similarly, an unemployed agent's income is composed of receipt of insurance payment, interest, dividend payment and net transfer from government; and the income is allocated among consumption, investment and insurance premium. The budget constraint for an unemployed agent is

$$c_{2,t} + a_{2,t+1} - (1 - \delta_k)a_{2,t} + p_t b_t \leq b_t + u_t a_{2,t} + \pi_t + T_t.$$

The household's problem is to maximize the expected discounted utility,

$$E_0 \sum_{t=0}^{\infty} \beta^t \{n_t [U(c_{1,t}) + \xi H(1 - h_{1,t})] + (1 - n_t) [U(c_{2,t}) + \xi H(1)]\},$$

with probability n_t that the household is employed, and with probability $(1 - n_t)$ that the household is unemployed, subject to the above employment contingent budget constraints, where the agent takes $\{w_t, u_t, \pi_t, n_t\}$ as given.

In the presence of a costless competitive insurance market, it can be shown that households choose to insure themselves fully in equilibrium. Consequently, the agents are ex ante identical, and $c_{1,t} = c_{2,t}$, $a_{1,t} = a_{2,t}$, $b_t = w_t h_t$, $p_t = (1 - n_t)$.

Given that the agents are ex ante identical, the household's optimization problem can be rewritten as

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \{U(c_t) + n_t \xi H(1 - h_t) + (1 - n_t) \xi H(1)\}$$

subject to

$$c_t + a_{t+1} - (1 - \delta_k)a_t = u_t a_t + w_t n_t h_t + \pi_t + T_t,$$

where the household takes $\{n_t, w_t, u_t, \pi_t\}$ as given.

Two kinds of disturbances will be introduced later: a technology shock and a government spending shock. The government spending shock is of particular interest in this paper.

The Lagrangian associated with the household's optimization problem is

$$L_1 = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t [U(c_t) + n_t \xi H(1 - h_t) + (1 - n_t) \xi H(1)] \right. \\ \left. + \sum_{t=0}^{\infty} \beta^t \lambda_t [u_t a_t + w_t n_t h_t + \pi_t - c_t - a_{t+1} + (1 - \delta_k) a_t + T_t] \right\},$$

where a_0 is given and λ_t is the multiplier attached to the t -period resource constraint.

The efficiency conditions are

$$\begin{aligned} U'(c_t) &= \lambda_t, & (a) \\ \xi H'(1 - h_t) &= \lambda_t w_t, & (b) \\ \lambda_t &= E_t \{ \beta \lambda_{t+1} [u_{t+1} + (1 - \delta_k)] \}, & (c) \\ c_t + a_{t+1} &= (1 - \delta_k) a_t + T_t + u_t a_t + w_t n_t h_t + \pi_t, & (d) \end{aligned} \tag{1}$$

for $t = 0, 1, \dots, \infty$ and the transversality condition is

$$\lim_{t \rightarrow \infty} \beta^t E_0 \{ \lambda_t a_{t+1} \} = 0.$$

The household selects c_t , h_t and a_t in a dynamically efficient manner. In (1.a), λ_t represents the shadow value of c_t . The equation states that the household equates the marginal utility of date t 's consumption to its opportunity cost in terms of utils. Equation (1.b) equates the marginal utility of leisure to the value of foregone earnings. The opportunity cost of investment is equal to its future discounted returns in (1.c). Equation (1.d) is the budget constraint.

3.2 Firms

In each period, a firm's economic activities include renting capital service, hiring workers, creating job vacancies, organizing production and selling products.

A firm employs many workers, and on average, it is large enough to eliminate all uncertainty about the flow of its labor force. The firm's labor force is determined by the inflow, new hires, and the outflow, separations. The separation rate, δ_n , is exogenous and constant over time.

The firm creates vacancies (o_t). The new hires (m_t) are determined by the number of vacancies and the success rate (θ_t) at which vacancies become filled, specifically,

$$m_t = \theta_t o_t.$$

The success rate is exogenous to the firm, and it is governed by the efficiency of the matching process in the labor market. For the firm, the law of motion of employment (n_t) is

$$n_{t+1} = (1 - \delta_n)n_t + m_t,$$

where m_t is the inflow of employment and $\delta_n n_t$ is the outflow of employment, or the flow from employment to unemployment.

Creating a vacancy is costly and the firm has to spend resources on each job opening. The recruiting cost embodies the cost incurred when the firm advertises the job opening, recruits candidates, trains the successful candidate and organizes his job. In the dynamic equilibrium, vacancies reflect recruiting effort and change in response to expectations about profitability.

The firm's output q_t is determined by a Cobb-Douglas production technology:

$$q_t = f(k_t, n_t h_t; z_t) = k_t^\alpha (z_t n_t h_t)^{1-\alpha},$$

where

k_t = capital stock at period t ;

h_t = hours provided by a worker;

z_t = an aggregate exogenous shock to technology;

and $0 < \alpha < 1$.

We assume the z_t process is a logarithmic random walk with drift:

$$\ln(z_t) = \ln(z_{t-1}) + \ln(z) + \epsilon_{z,t},$$

where the innovation, $\epsilon_{z,t}$, is assumed to be identically and independently distributed through time with zero mean. The growth rate of this economy is $\ln(z)$.

A firm's profit is the difference between the revenue from the sale of output and the cost of hiring labor, renting capital services and creating vacancies. We treat output as the numeraire, all factor prices are relative prices. The firm's pure profit in period t is

$$\pi_t = q_t - u_t k_t - w_t n_t h_t - \kappa_t o_t,$$

where

u_t = rental rate of capital service at t ;

w_t = wage rate at t ;

κ_t = recruiting cost per vacancy at t .

Given the prices $\{(u_t, w_t, \kappa_t)\}_{t=0}^{\infty}$, the separation rate δ_n , the success rate θ_t and the initial labor force n_0 , the problem faced by a firm is to choose the amount of capital services, the number of vacancies and output $\{(k_t, o_t, q_t)\}_{t=0}^{\infty}$ that maximize the present value of profits. Thus its decision problem is

$$\max E_0 \sum_{t=0}^{\infty} \prod_{j=0}^t R_j^{-1} \pi_t$$

subject to the following constraints:

$$\begin{aligned} q_t &= f(k_t, n_t h_t; z_t), \\ n_{t+1} &= n_t(1 - \delta_n) + \theta_t o_t, \end{aligned}$$

where $R_t = u_t + 1 - \delta_k$. The firm takes $k_0, o_0, \delta_n, u_t, w_t, n_t, h_t, \kappa_t$, and θ_t as given.

The Lagrangian of the firm's problem is

$$L_2 = E_0 \sum_{t=0}^{\infty} \prod_{j=0}^t R_j^{-1} \{ f(k_t, n_t h_t; z_t) - u_t k_t - w_t n_t h_t - \kappa_t o_t - \{ \eta_t (n_{t+1} - (1 - \delta_n) n_t - \theta_t o_t) \} \}.$$

The efficiency conditions are the following:

$$\begin{aligned} f_1(k_t, n_t h_t; z_t) &= u_t, & (a) \\ \kappa_t &= \eta_t \theta_t, & (b) \\ \eta_t &= ER_{t+1}^{-1} [f_2(k_{t+1}, n_{t+1} h_{t+1}; z_{t+1}) h_{t+1} - w_{t+1} h_{t+1} + (1 - \delta_n) \eta_{t+1}], & (c) \\ n_{t+1} &= (1 - \delta_n) n_t + \theta_t o_t. & (d) \end{aligned} \tag{2}$$

The act of job creation is a decision by the firm to fill a vacant job at some cost. In equilibrium, the aggregate number of vacancies adjusts to eliminate any rent attributable to holding a job vacancy. Equation (2.b) is a free-entry condition. It equates the recruiting cost of a vacancy to the expected present value of holding a vacancy. The variable η_t can be explained as the capital value of a hired worker to the firm.⁷ Equation (2.c) defines the shadow value η_t as the profit the new worker will make to the firm at $t + 1$ plus the expected shadow value which is 0 with probability δ_n if the worker separates from the firm, and is η_{t+1} if he remains to work in the following period.

⁷This becomes clear if we write out the complete expression from (2.c)

$$\eta_t = E_t \sum_{i=1}^{\infty} \prod_{j=0}^i R_j^{-1} (1 - \delta_n)^{(i-1)} (f_2(k_{t+i}, n_{t+i} h_{t+i}; z_{t+i}) h_{t+i} - w_{t+i} h_{t+i}).$$

In each period, the firm realizes some economic rent, $f_2 h - w h$, from a retained worker. The worker hired at t will remain in this firm at $t + 1$ and has probability δ_n to leave the firm in the periods after. Thus η_t is the summation of the expected economic rent induced from a job filled in at t .

The Euler conditions satisfied by the optimal sequences of k_t and o_t are:

$$\begin{aligned} f_1(k_t, n_t h_t; z_t) &= u_t, & (a) \\ \kappa_t / \theta_t &= E_t R_{t+1}^{-1} \{ f_2(k_{t+1}, n_{t+1} h_{t+1}; z_{t+1}) h_{t+1} \\ &\quad - w_{t+1} h_{t+1} + (1 - \delta_n) \kappa_{t+1} / \theta_{t+1} \}. & (b) \end{aligned} \quad (3)$$

We observe that if $\kappa_t = 0$, equation (3.b) would reduce to the standard marginal productivity condition for employment.

3.3 Job Matching and Wage Determination

According to Blanchard and Diamond (1989), the labor market in the U.S. is highly effective in allocating workers to jobs. The flows are large in proportion to stocks. The average duration of unemployment rarely exceeds 3 months; and the average duration of vacancies does not exceed a month. This implies the simultaneous coexistence of unemployment and vacancies. The study of worker flows to and from employment has generated a considerable literature.⁸ The theoretical foundation of the matching process arises out of search and matching theory (see Pissarides, 1990). The basic idea is that the recruiting effort of employers and the search effort of workers serve as inputs in a market matching function that generates new hires. The job vacancies and unemployed workers that are matched at any point in time are randomly selected from the sets o_t and $1 - n_t$. $(1 - n_t)/o_t$ is a measure of labor market tightness.

In this paper, we assume that all the unemployed workers search for jobs.⁹ The rate at which vacant jobs and searching workers match is determined by an increasing, concave, and

⁸Devine and Kiefer (1991) include an extensive review of panel-based studies. Mortensen and Pissarides (1993) and Mortensen (1994) study the interaction of job creation and job destruction in a dynamic stochastic equilibrium framework.

⁹This assumption could be relaxed if we consider a situation with discouraged workers. More people participate when wages are higher and labor market tightness is higher. The dependence of the participation rate on labor market tightness is called the "discouraged worker effect". When the rate at which unemployed workers find jobs falls, fewer workers participate.

homogeneous of degree one function $m(o_t, 1-n_t)$ where o_t and $1-n_t$ respectively represent the number of jobs that employers are attempting to fill, and the number of workers seeking those jobs. Under the assumptions of random matching and constant returns, the probabilistic rate at which vacancies are filled is $\theta_t = m(o_t, 1-n_t)/o_t = m(1, (1-n_t)/o_t)$. The process that changes the state of a vacant job is Poisson with rate θ_t . The mean duration of a vacant job is $1/\theta_t$. Unemployed workers move into employment according to a Poisson process with rate $m(o_t, 1-n_t)/(1-n_t) = \theta_t o_t/(1-n_t)$. The mean duration of unemployment is $d_t = (1-n_t)/m_t$.

In this paper, we assume the matching process is governed by a well behaved Cobb-Douglas matching function,¹⁰

$$m(o_t, 1-n_t) = \chi o_t^\psi (1-n_t)^{(1-\psi)} \leq \min\{o_t, 1-n_t\}.$$

The wage rate is determined by decentralized bargaining between workers and firms. The match between the worker and the firm creates a surplus that must be bargained over. The wage rate is given by implicit bargaining at the individual level. The outcome of the bargaining is simply assumed as:

$$w_t = (1-\gamma)f_2(k_t, n_t h_t; z_t),$$

¹⁰The matching function in this paper is assumed to be constant returns to scale. According to Blanchard and Diamond (1989), there is empirical evidence suggesting constant or mildly increasing return to scale. The assumption of inequality in our matching function implies that the mean duration of vacancy o_t/h_t is more than one month and also the mean duration of unemployment $(1-n_t)/h_t$ is more than one month. There is no question about the assumption that the mean duration of unemployment is more than one month; for example, according to Blanchard and Diamond (1989), it is about three months. However, according to the same study, the average duration of vacancies is less than one month. But van Ours and Ridder (1992) point out that a distinction should be made between the time a help-wanted advertisement is removed and the time it actually takes to fill a vacant position. They report that while seventy-five percent of all vacancies are filled by applicants who arrive in the first two weeks, it takes on average forty-five days to select a suitable employee from the pool of applicants. In this paper, the help-wanted advertising index is used as the proxy of vacancies.

where γ is a constant ($0 < \gamma < 1$) and a measure of the bargaining power of the firm. Thus, the wage rate is proportional to hourly productivity. The standard model equates the wage rate to the marginal product of labor. Thus the wage equation in the standard model can be viewed as a special case of the wage equation in this paper ($\gamma = 0$).

Firms spend resources on hiring, and this activity is an economic one just like production. To be consistent with balanced growth, recruiting cost per vacancy κ_t is assumed to have the same growth rate as the technological level z_t . In a detrended economy, the recruiting cost is constant, $\kappa_t = \kappa$.

(2.b) is then rewritten as

$$-\frac{\kappa_t o_t}{m(o_t, 1 - n_t)} + E_t R_{t+1}^{-1} \left\{ f_2(k_{t+1}, n_{t+1} h_{t+1}; z_{t+1}) h_{t+1} \gamma + \frac{(1 - \delta_n) \kappa_{t+1} o_{t+1}}{m(o_{t+1}, 1 - n_{t+1})} \right\} = 0.$$

3.4 Government

Government spending is exogenous. The government finances its consumption solely by lump-sum taxation. This paper does not consider distortionary taxes. The government faces the following budget constraint

$$g_t + T_t = 0.$$

3.5 A Competitive Equilibrium

Definition. A competitive equilibrium is a set of prices $\{u_t, w_t\}_{t=0}^{\infty}$, an allocation $\{(c_t, a_t, h_t, \pi_t)\}_{t=0}^{\infty}$ for a typical household and an allocation $\{(k_t, o_t, \pi_t)\}_{t=0}^{\infty}$ for a representative firm, given exogenous sequences of technology shocks, $\{z_t\}_{t=0}^{\infty}$ and government spending, $\{g_t\}_{t=0}^{\infty}$, such that

(1) given $\{u_t, w_t, \pi_t, T_t\}$, $\{c_t, a_t, h_t\}$ solve the household's problem;

(2) given $\{u_t, w_t\}$, $\{o_t, k_t\}$ solve the firm's problem;

(3) w_t satisfies the bargaining solution;

(4) government's budget constraints are satisfied;

(5) all markets clear,

$$a_t = k_t, \theta_t = m(o_t, 1 - n_t)/o_t.$$

The equilibrium conditions are summarized as follows:

$$\begin{aligned} U'(c_t) &= \beta E_t \{ (1 + f_1(k_{t+1}, n_{t+1}h_{t+1}; z_{t+1}) - \delta_k) U'(c_{t+1}) \}, & (a) \\ \xi H'(1 - h_t) &= (1 - \gamma) f_2(k_t, n_t h_t; z_t) U'(c_t), & (b) \\ n_{t+1} &= (1 - \delta_n) n_t + m(o_t, 1 - n_t), & (c) \\ \kappa_t o_t / m(o_t, 1 - n_t) &= E_t R_{t+1}^{-1} \{ f_2(k_{t+1}, n_{t+1}h_{t+1}; z_{t+1}) h_{t+1} \gamma \\ &\quad + (1 - \delta_n) \kappa_{t+1} o_{t+1} / m(o_{t+1}, 1 - n_{t+1}) \}, & (d) \\ f(k_t, n_t h_t; z_t) &= c_t + k_{t+1} - (1 - \delta_k) k_t + g_t + \kappa_t o_t. & (e) \end{aligned} \quad (4)$$

These equations are used in GMM to get the estimates of the parameters.

4 Estimation Method (GMM) and Data Measures

The Generalized Method of Moments (GMM), developed by Hansen (1982) and Hansen and Singleton (1982), is used to estimate the model. Like Christiano and Eichenbaum (1992), Burnside, Eichenbaum and Rebelo (1993) and Burnside and Eichenbaum (1996), we use an exact identified GMM estimator.

The GMM criterion is set up so that the estimated model exactly matches the sample analog of certain unconditional moments of the data generating process.

Government spending g_t is assumed to be exogenous, following the process

$$\ln(g_t) = \ln(z_t) + \mu_g + \ln(\tilde{g}_t),$$

where \tilde{g}_t is the trendless component of g_t . \tilde{g}_t has zero mean and follows

$$\ln(\tilde{g}_t) = \rho_g \ln(\tilde{g}_{t-1}) + \epsilon_{gt},$$

where $|\rho_g| < 1$, ϵ_{gt} is the innovation in $\ln(\tilde{g}_t)$ with zero mean and standard deviation σ_g . This specification implies that government spending grows at the same rate as that of total output so that a balanced growth path exists.

The structure parameters in the models are:

Preference: β, ξ

Technology: $\alpha, \delta_k, z, \sigma_z$

Labor Search: $\kappa, \gamma, \delta_n, \chi, \psi$

Government: μ_g, ρ_g, σ_g .

The parameters β, κ, ψ are not estimated. Instead, β is set at $1.03^{-0.25}$. κ is set to 2 such that the share of recruiting cost is around 4%. Alternatively, κ can be estimated by setting the value of γ , which reflects the bargaining power of a firm. Larger γ indicates greater bargaining power for a firm. γ and κ are closely related. A higher γ means more profit to the firm, so the firm can spend more in recruitment, thus allowing a larger κ . ψ is set to 0.6, a value estimated by Blanchard and Diamond (1989) based on the 1968 – 81 sample period.

4.1 The Moment Restrictions Underlying the GMM estimator

The time series used in GMM include private consumption, c_t , gross investment, i_t , capital stock, k_t , government spending, g_t , employment rate, n_t , hours per worker, h_t , vacancy rate, o_t , and average duration of unemployment, d_t . (Appendix 1 contains a detailed explanation of these series.)

Different from previous studies, output in this model equals aggregate demand plus resource costs in labor market search, i.e. the summation of c_t, i_t, g_t and $\kappa_t o_t$. q_t is not directly

observable because data on recruiting costs are not available. We adopt the following strategy to solve this problem. As assumed earlier, recruiting cost per vacancy has to grow at the same rate as the technology level z_t to meet the requirement of balanced growth. In this model, q_t also grows at the same rate. So we assume κ_t is proportional to q_t , $\kappa_t = \kappa q_t$. Then output can be written in terms of available time series and a parameter κ , that is, $q_t = (c_t + i_t + g_t)/(1 - \kappa o_t)$.

The parameter δ_k is identified by a condition

$$E[\ln(\delta_{kt}) - \ln(\delta_k)] = 0, \quad (5)$$

where $\delta_{kt} = 1 + (i_t - k_{t+1})/k_t$.

The parameter α is identified by the intertemporal Euler equation

$$E[1/\beta - (\alpha q_{t+1}/k_{t+1} + (1 - \delta_{kt}))c_t/c_{t+1}] = 0. \quad (6)$$

By assuming the z_t process as follows,

$$\ln(z_{t+1}) = \ln(z_t) + \ln(z) + \epsilon_{z,t+1},$$

and the production function, the technology shock is derived as

$$\ln(z_t) = \frac{1}{1 - \alpha} [\ln(q_t) - \alpha \ln(k_t)] - \ln(n_t h_t).$$

$\ln(z)$ can be identified by the balanced growth restriction which says that the mean growth rate of output coincides with that of technology.

$$E[\ln(q_t) - \ln(q_{t-1}) - \ln(z)] = 0, \quad (7)$$

also σ_z can be identified from the condition,

$$E[(\ln(z_t) - \ln(z) - \ln(z_{t-1}))^2 - \sigma_z^2] = 0. \quad (8)$$

The parameter ξ is identified through the intratemporal efficiency condition,

$$E[\xi - (1 - \gamma)(1 - \alpha) \frac{1 - h_t q_t}{n_t h_t c_t}] = 0. \quad (9)$$

Now we are going to identify κ . From the Cobb-Douglas production function, we have

$$f_2(k_t, n_t h_t; z_t) = (1 - \alpha)q_t / (n_t h_t),$$

$$R_t = 1 - \delta_k + \alpha q_t / k_t.$$

Rewrite the Euler equation (3.b) of n_t as

$$E\{-\kappa o_t / n_{t+1} - (1 - \delta_n)n_t(1 - \delta_K + \alpha q_{t+1} / k_{t+1}) + q_{t+1} / q_t((1 - \alpha)\gamma / n_{t+1} + (1 - \delta_n)\kappa o_{t+1} / n_{t+2} - (1 - \delta_n)n_{t+1})\} = 0. \quad (10)$$

Now consider government spending. The stationary component of g_t , \tilde{g}_t , can be written as

$$\ln(\tilde{g}_t) = \ln(g_t) - \frac{1}{1 - \alpha}(\ln(q_t) - \alpha \ln(k_t)) + \ln(n_t h_t) - \mu_g.$$

The following three moment restrictions can be used to estimate μ_g , ρ_g , and σ_g ,

$$E[\ln(\tilde{g}_t)] = 0, \quad (11)$$

$$E[\ln(\tilde{g}_t) - \rho_g \ln(\tilde{g}_{t-1})] \ln(\tilde{g}_{t-1}) = 0, \quad (12)$$

$$E[(\ln(\tilde{g}_t) - \rho_g \ln(\tilde{g}_{t-1}))^2 - \sigma_g^2] = 0. \quad (13)$$

Finally the following two moment conditions are used to estimate δ_n and χ ,

$$E(n_{t+1} - (1 - \delta_n)n_t - m_t) = 0, \quad (14)$$

$$E[(n_{t+1} - (1 - \delta_n)n_t - m_t)t/T] = 0, \quad (15)$$

where $m_t = \chi o_t^\psi (1 - n_t)^{1-\psi}$.

Denote $\Psi = \{\delta_k, \alpha, \xi, \gamma, \delta_n, \ln(z), \sigma_z, \mu_g, \rho_g, \sigma_g, \chi\}$ as the set of parameters to be estimated by GMM. We have 11 parameters in Ψ to be estimated and 11 moments conditions, equations (5) to (15), thus forming an exact identification system. The application of GMM requires that each equation includes only stationary variables. The moment conditions relating to Ψ already satisfy the requirement, because c_t , q_t , k_t and g_t all grow at rate $\ln(z)$, and n_t , h_t and o_t are stationary. Therefore the variables involved δ_{kt} , q_t/k_t , c_t/c_{t+1} , q_t/c_t , $(1 - h_t)/(n_t h_t)$, o_t/n_t , q_{t+1}/q_t , and n_{t-1}/n_t are stationary.

4.2 Data Measures

The following time series are expressed in quarterly real per capita terms. Detailed data description is given in Appendix 1.

Private consumption, c_t , is measured as personal expenditure on nondurable goods plus services. Government spending, g_t , is measured by real government purchases of goods and services. The capital stock, k_t , is measured as a net, end-of-period stock consisting of non-residential, fixed capital owned by the private and government sectors plus government and private residential capital, and consumer durable goods. Gross investment, i_t , is measured as the sum of private investment and government investment corresponding to the above capital stock. The employment rate, n_t , is measured as the ratio of the number of employed persons to the non-institutional population, aged 16 and over. Average working hours, h_t , is measured as the ratio of the aggregate hours of wage- and salary-earning workers in non-agricultural establishments to the number of persons employed. The vacancy rate, o_t , is measured as the ratio of help-wanted advertising to the non-institutional population.

4.3 GMM Estimation Results

For the purpose of comparison, a version of the Burnside, Eichenbaum and Rebelo's (1993) labor hoarding model is also considered and referred as the *benchmark model*.¹¹ In the original BER model, effort is flexible and the shift length is fixed. To facilitate comparison, we reinterpret effort to be hours worked per worker and set shift length to be one. Appendix 2 presents a more detailed description of the BER model. The parameters in the BER model to be estimated include $\{\delta_k, \alpha, \xi, \ln(z), \sigma_z, \mu_g, \rho_g, \sigma_g, e\}$, where e is a fixed cost to go to work in terms of hours of foregone leisure. The model developed in Section 3 above is referred as the *search model*. The parameters of the benchmark model and the search model are estimated using the same data set. Model parameter estimates and standard errors are reported in Table 1.

The estimate of the capital depreciation rate for both models is 0.02. The capital share of output, α , is estimated to be around 0.30. These estimates are similar to those in Christiano and Eichenbaum (1992) and Burnside and Eichenbaum (1996). The separation rate, δ_n , is estimated to be 0.11. In steady state, the average duration of a job advertisement is equal to $o/\delta_n n = 0.29$ month. The matching efficiency coefficient in the matching function, χ , is estimated to be 0.96.

5 Near Steady State Dynamics of the Model

In order to examine the dynamic responses of the economy to different persistence levels of government spending shocks, we adopt the method of King, Plosser and Rebelo (1990) to determine the near steady state dynamics of the model.

In this model, there are two state variables, the capital stock k_t and employment n_t , and

¹¹We thank an anonymous referee for this suggestion.

also two co-state variables, λ_t in the household's problem and η_t in the firm's problem. For control variables, the households decide on consumption c_t and hours worked per worker h_t , and the firm decides on vacancies o_t . By the law of motion of the labor force, vacancies can be expressed in terms of employment, thus the problem can be rewritten to have four state and co-state variables and two control variables.

In the following analysis based on the search model, four kinds of shocks with different degrees of persistence are considered: a transitory shock ($\rho_g = 0$); persistent shocks, ($\rho_g = 0.93$), ($\rho_g = 0.95$) and ($\rho_g = 0.97$), where ($\rho_g = 0.95$) corresponds to the GMM estimate in the last section, and ($\rho_g = 0.93$) and ($\rho_g = 0.97$) correspond to minus-one and plus-one standard deviations in the persistence level. Also, we will compare the VAR model to the search model which has ($\rho_g = 0.95$).

In the benchmark model, we also consider four kinds of shocks with different degrees of persistence: a transitory shock ($\rho_g = 0$); persistent shocks, ($\rho_g = 0.98$), ($\rho_g = 0.97$) and ($\rho_g = 0.99$), where ($\rho_g = 0.98$) corresponds to the GMM estimate in the last section, and ($\rho_g = 0.97$) and ($\rho_g = 0.99$) are close to minus-one and plus-one standard deviations.

Figures 3 to 6 plot the dynamic responses of selected variables in the benchmark and search models to a one-standard-deviation shock to government consumption.

5.1 Total Hours Worked

In the benchmark model with a positive income effect on leisure, persistent changes in government spending always have an effect on total hours worked and output that is larger than the effect of transitory changes. The response functions in Figure 3(b) show that a transitory shock ($\rho_g = 0$) increases hours by 0.02%, while persistent shocks ($\rho_g = 0.98$) increase hours

by 0.35%.¹² The reason is well explained in Aiyagari, Christiano and Eichenbaum (1992). Holding private investment constant, the effect of government spending on hours worked is positive due to a negative wealth effect. A transient increase in government spending reduces investment, but a persistent increase in government spending either increases investment or does not reduce it by as much as in the transient case. Thus persistent changes in government spending generate larger contemporaneous effects on both hours worked and output than transient changes.

Figure 3(a) plots the impulse responses of total hours worked in the search model. These responses are the combination of the responses of employment and hours worked per worker which we will explain in the next section. The time paths of total hours worked are similar to those in the benchmark model, but with smaller magnitudes.

5.2 Employment and Hours Worked per Worker

In the benchmark BER model, hours worked per worker increases in the first quarter and then returns to the steady state level, and the increase in total employment starts in the second quarter and returns to the steady state gradually from above (Figure 3(d),4(b)). The reason is well explained in BER (1993) and Hall (1996). Given a positive government expenditure shock, the only contemporaneous labor margin that can be adjusted is the hours worked per worker, which increases due to a negative wealth effect. In the second quarter, employment starts to increase so that the hours worked returns to its steady-state level since, in the steady state, increasing employment reduces an agent's expected utility less

¹²These magnitudes of the responses are similar to Campbell (1994). In the model with indivisible labor (Table 7, $\sigma_n = \infty$), the hours worked elasticities with government spending are 0.04, 0.06, 0.27, 0.43, corresponding to persistence of government spending of 0.00, 0.50, 0.95, and 1.00. If $g = 0.2$ and $n = 1/3$, the changes are 0.06, 0.1, 0.45, 0.72 base points, given a base point change in government spending. The output changes are 0.1, 0.2, 0.9 and 1.45 base points, given a base point change in g and $q = 1$.

than increasing the hours worked per worker. (Utility is linear over employment, but convex over effort.)

In the search model, hours worked per worker and employment respond differently to a government spending shock (Figure 3(c),4(a)). The shock affects them through different mechanisms. Hours worked per worker are determined by the household through intertemporal substitution. Employment is determined by job destruction and creation in the labor market. Changes in employment in this model depend crucially on the decision by the firm to create a vacant job at some cost. In the dynamic equilibrium, vacancies reflect recruiting effort and move in response to the expectation of the profitability of a successful match.

Either a transient or persistent government spending shock increases hours worked per worker in the first period. More persistent shocks lead to larger increases in hours worked per worker. In the following periods, hours decrease and gradually return to the steady state value.

Compared to the response of hours worked per worker, employment responds to the shock slowly. The transitory shock ($\rho_g = 0$) decreases employment, and employment reaches its lowest point six periods after the shock, then employment increases gradually and eventually returns to its steady state value.¹³

The explanation of employment behavior is as follows. In this model, job creation is determined by job openings of the firm. The firm increases or decreases job openings based on the expected capital value of a hired worker to the firm. A higher value of a hired worker to the firm encourages the firm to create more vacancies. The capital value of a hired worker to the firm is the expected discounted economic rent that a worker brings to the firm. There

¹³A persistent shock may decrease or increase employment depending on the degree of the persistence. Numerical experiments show that a random walk government spending shock with ($\rho_g = 1$) increases employment.

are two factors that affect the capital value. One is real interest rate and the other is the pure economic rent in each period. Higher interest rates lower the expected capital value of a hired worker. Higher economic rent increases the capital value.

Negative wealth effects bring private consumption below its steady state value in the impact period, and then consumption gradually returns to its steady state value (Figure 5(a)). The convergence is monotonic.¹⁴ Under the demand shock, there exists excess demand in the goods market at the prevailing interest rate, and the interest rate must go up to clear the goods market (Figure 5(c)). The model shows that an increasing private consumption time path from below the steady state is accompanied by an above steady state average interest rate.

A worker's economic rent is determined by his/her productivity and hours. A shock may either increase or decrease economic rent, because the response of the productivity of labor may be opposite to that of hours (Figure 6(a),(b)). The figures show that even though economic rent increases to a shock with $0 < \rho_g \leq 0.97$ (Figure 3(a) and 6(a)), the negative interest rate effect on the capital value still dominates the positive economic rent effect. Thus the expected capital value decreases and vacancies are less (Figure 4(c),(d)).¹⁵ In Figure 4(a), the employment levels for shocks with higher persistence levels ($\rho_g = 0.93, 0.95$) are lower than that for a transitory shock ($\rho_g = 0$). We also observe that the employment levels with ($\rho_g = 0.95, 0.97$) are above that of ($\rho_g = 0.93$).

We can understand the above observation by viewing the responses of the shadow values of a hired worker and vacancies (Figure 4(c),(d)). The shadow value corresponding to a shock with ($\rho_g = 0$) is higher than those of ($\rho_g = 0.95$) and ($\rho_g = 0.97$); and the shadow values

¹⁴A shock may crowd in or crowd out private investment depending on the value of ρ_g . Numerical experiments show that a temporary shock with persistence ρ_g close enough to one crowds in private investment.

¹⁵However, for shock with ρ_g close enough to 1, the positive rent effect dominates the negative interest rate effect, resulting in an increase to the expected capital value.

for $(\rho_g = 0.95)$ and $(\rho_g = 0.97)$ are higher than the one with $(\rho_g = 0.93)$. Correspondingly, the case with the transitory shock has more vacancies than the cases with $(\rho_g = 0.93)$ and $(\rho_g = 0.95)$, and the cases with $(\rho_g = 0.95)$ and $(\rho_g = 0.97)$ have more vacancies than the case with $(\rho_g = 0.93)$.

5.3 Output Effects

The output effects are similar in these two models (Figure 6(c), (d)). A shock in government spending always increases output, with more persistent shocks leading to greater increases. That is, we observe multiplier effects with persistent government spending shocks. In the search model, an increase in government spending unambiguously raises hours worked per worker, but may increase or decrease the capital stock and employment. The results indicate that the positive hours effect dominates the other two effects regardless of the persistence of the shock.

5.4 Comparison of Hours and Employment Effects of the Search Model and VAR Models

Another comparison is between the VAR models in Section 2 and the search model with a shock $(\rho_g = 0.95)$ using the GMM estimate. In the search model, a one standard deviation increase in government spending increases hours worked per worker by 0.25% in the impact period, and then hours worked per worker gradually returns to the steady state. In the VAR models, hours worked per worker increase by 0.24% during the first 5 quarters and then decrease.

The employment time paths of these two models are similar, employment gradually decreases in the two models after a shock, and reaches its lowest level in the 15th to 20th quarters. But the decrease in the search model is much smaller in magnitude than that in

the VAR models. However, the employment response in the VAR models is not significantly different from zero. Thus, qualitatively, the search model can generate similar responses of employment and hours worked per worker to those in the empirical VAR studies.

6 Conclusions

This paper focuses on the effects of temporary government spending shocks in the U.S. economy on employment, hours worked per worker and output. Several VAR models demonstrate that a temporary innovation in government spending raises both hours worked per worker and output, but lowers the employment level. We construct a stochastic general equilibrium model in which employment is determined by a matching mechanism. The results show that, in contrast to a reinterpreted Burnside, Eichenbaum and Rebelo's (1993) labor hoarding model, the search model can generate similar responses of hours worked per worker and employment to those of VAR models.

Appendix 1: Data Source Description and Transformation

Raw Data Source and Series

(1) U.S. National Income and Product Accounts Tables, Bureau of Economic Analysis, U.S. Department of Commerce. Quarterly data. In 1987 dollars (Billions).

CC – Personal Consumption Expenditures

GC – Government Purchases of Goods and Services

GFD – Federal National Defence (deflated by GDP deflator)

GDPC – Gross Domestic Product

JGDP – Implicit Deflator: Gross Domestic Product

(2) Fixed Reproducible Tangible Wealth in the U.S. tables. Bureau of Economic Analysis, U.S. Department of Commerce. Annual data. In 1987 dollars (Millions).

NBNTIC – Nonres Pvt Cap, by Leg Org, Tot All Ind:Net Stock, Eq & Str

IBNTIC – Nonres Pvt Cap, by Leg Org, Tot All Ind: Invest., Eq & Str

NBNGOAMC – Nonres Gvt-Owned,Pvt Oper Cap, All Agen-Mfg:Net Stk, Eq & Str

IBNGOAMC – Nonres Gvt-Owned,Pvt Oper Cap, All Agen-Mfg: Invest., Eq & Str

NEDGTC – Consumer-Total Durable Goods: Net Stock, Eq

IEDGTC – Consumer-Total Durable Goods: Investment, Eq

NBRTOTGC – Res Cap, by Legal Org, All Own, inc Gvt:Net Stock, Eq & Str

IBRTOTGC – Res Cap, by Legal Org, All Own, inc Gvt: Invest., Eq & Str

NBNGFC – Nonres Gvt-Owned Capital, Federal: Net Stock, Eq & Str

IBNGFC – Nonres Gvt-Owned Capital, Federal: Invest., Eq & Str

NBNSLC – Nonres Total State & Local Govt, Net Stock, Eq & Str

IBNGLC – Nonres Govt Capital: State & Local, Investment, Eq & Str

(3) Bureau of Labor Statistics, U.S. Department of Labor, seasonal adjusted monthly data.

LE – Civilians Employed (Thous)

LNAN – Employee Hours in Nonagricultural Est. (Bil. Hrs)

LHTNAGRA – Aggregate Hours of Wage and Salary Workers in Nonagr Estab (Bil. Hrs)

LENA – Civilians Employed: Nonagricultural Industries (SA, Thous.)

LR – Civilian Unemployment Rate (%)

LP – Civilian Participation Rate (%)

LNN – Civilian Noninstitutional Population (NSA, Thous.)

RATADVHW – The Ratio of Help-wanted advertisings to Persons Unemployed (%)

(4) CANSIM

TBR – 91-Day Treasury Bill yield (%)

Data Transformation

The following series are in per capita terms:

$$c = (CC/LNN) * 1000$$

$$g = (GC/LNN) * 1000$$

$$i = (IBNTIC + IBNGOAMC + IEDGTC + IBRTOTGC + IBNGFC + IBNSLC)/LNN$$

$$k = (NBNTIC + NBNGOAMC + NEDGTC + NBRTOTGC + NBNGFC + NBNSLC)/LNN$$

$$nl = (LHTNAGRA/LNN) * 1000 * 1000 / (1369 * 4)$$

$$n = LE/LNN$$

$$l = nl/n$$

$$v = RATADVHW * LP * LR * 0.0001$$

Appendix 2: A Version of Burnside, Eichenbaum and Rebelo's (1993) Labor Hoarding Model

The model economy is populated with a large number of infinitely lived individuals. To go to work, an individual must incur a fixed cost, e , denominated in terms of hours of forgone leisure. Once at work, an individual chooses hours worked h_t . The time endowment is normalized to 1. The momentary utility at time t is given by

$$\ln(c_t) + \xi n_t \ln(1 - e - h_t) + \xi(1 - n_t) \ln(1). \quad (16)$$

Output, y_t , is produced via the Cobb-Douglas production function

$$y_t = k_t^\alpha (z_t n_t h_t)^{1-\alpha}, \quad (17)$$

where $0 < \alpha < 1$, n_t denotes the total number of individuals going to work at time t , k_t denotes the beginning of period of capital stock, z_t represents the growth rate of exogenous labor-augmenting technological progress and it evolves according to

$$\ln z_t = \ln z_{t-1} + \ln z + \varepsilon_{zt}, \quad (18)$$

where ε_{zt} is the innovation to $\ln z_t$ with a standard deviation of σ_z . Firms commit to the number of workers employed before observing any shocks to the economy. After observing the shocks, firms can adjust the work hours of their employees.

The aggregate resource constraint is given by

$$c_t + k_{t+1} - (1 - \delta_k)k_t + g_t \leq y_t. \quad (19)$$

The parameter δ represents the depreciation rate on capital. The random variable g_t denotes time t government consumption which evolves according to

$$\ln g_t = \ln z_t + \mu_g + \ln \tilde{g}_t, \quad (20)$$

where \tilde{g}_t has the law of motion

$$\ln \tilde{g}_t = \rho_g \ln \tilde{g}_{t-1} + \varepsilon_{gt}, \quad (21)$$

where ε_{gt} is the innovation to $\ln(g_t)$ with standard deviation σ_g .

The social planner chooses a set of stochastic processes $\{k_{t+1}, n_{t+1}, h_t\}_{t=0}^{\infty}$ to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t [\ln(c_t) + \xi n_t \ln(1 - e - h_t) + \xi(1 - n_t) \ln(1)] \quad (22)$$

subject to (17)-(21) and k_0 and n_0 .

Except some notations, the only difference between this model and the one presented in BER is that instead of having agents choose effort with shift length fixed, we treat the product of the two as the hours worked per worker which is a choice variable of the households.

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Parameter	Benchmark Model		Search Model	
	Estimate	Standard Error	Estimate	Standard Error
δ_k	0.0202	0.0001	0.0204	0.0001
α	0.3027	0.0056	0.2958	0.0049
$\ln(z)$	0.0044	0.0008	0.0034	0.0008
σ_z	0.0122	0.0009	0.0128	0.0009
ξ	4.0955	0.0440	4.6151	0.0404
μ_g	-2.3773	0.0257	-2.4709	0.0225
ρ_g	0.9829	0.0142	0.9531	0.0225
σ_g	0.0193	0.0021	0.0127	0.0009
e	0.0974	0.0007		
δ_n			0.1140	0.0045
γ			0.0657	0.0022
χ			0.9602	0.0404

Table 1: GMM Estimates of Parameters in the Benchmark and Search Models

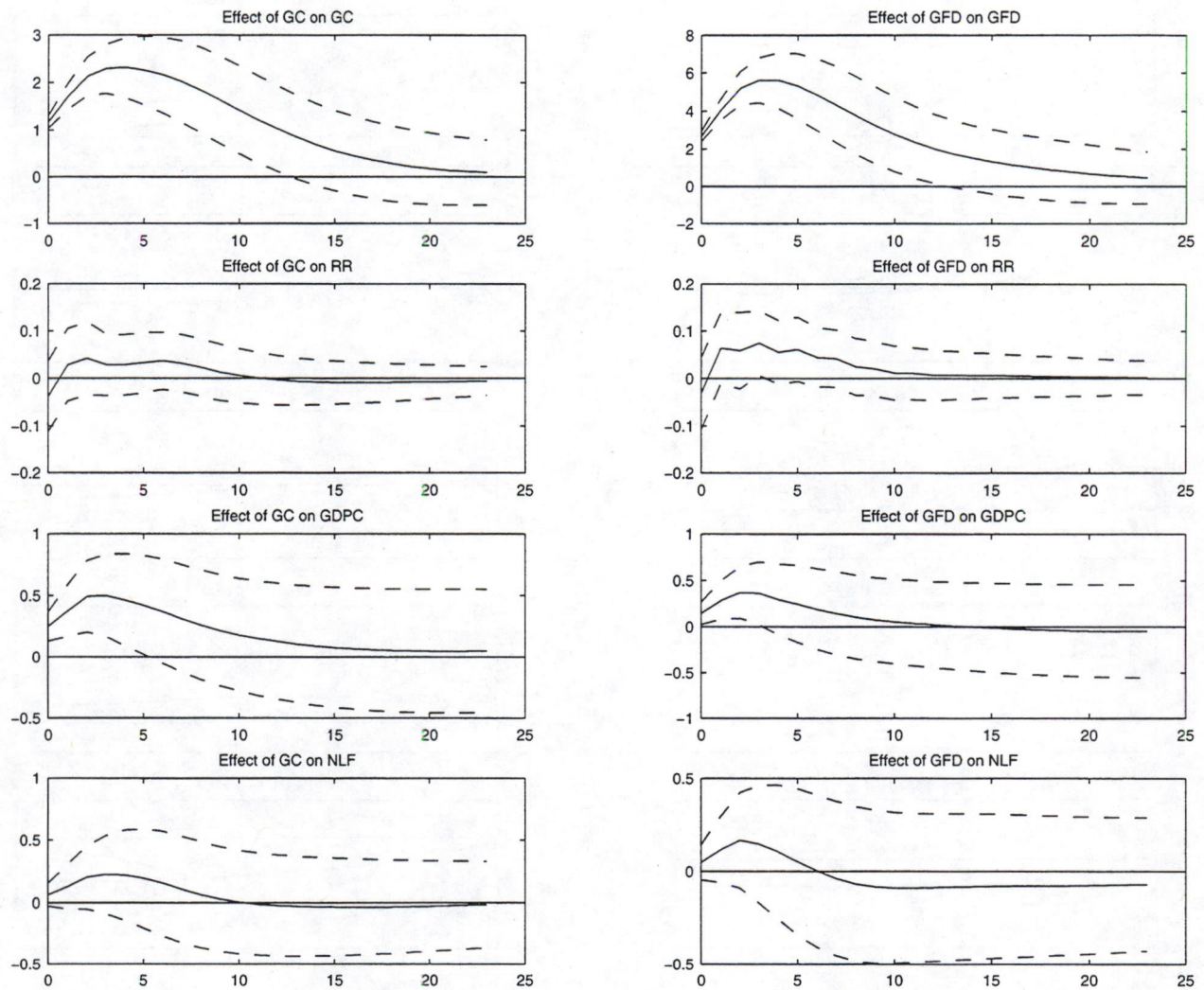


Figure 1: VAR: The Effect of Government Spending Shocks on Total Hours Worked

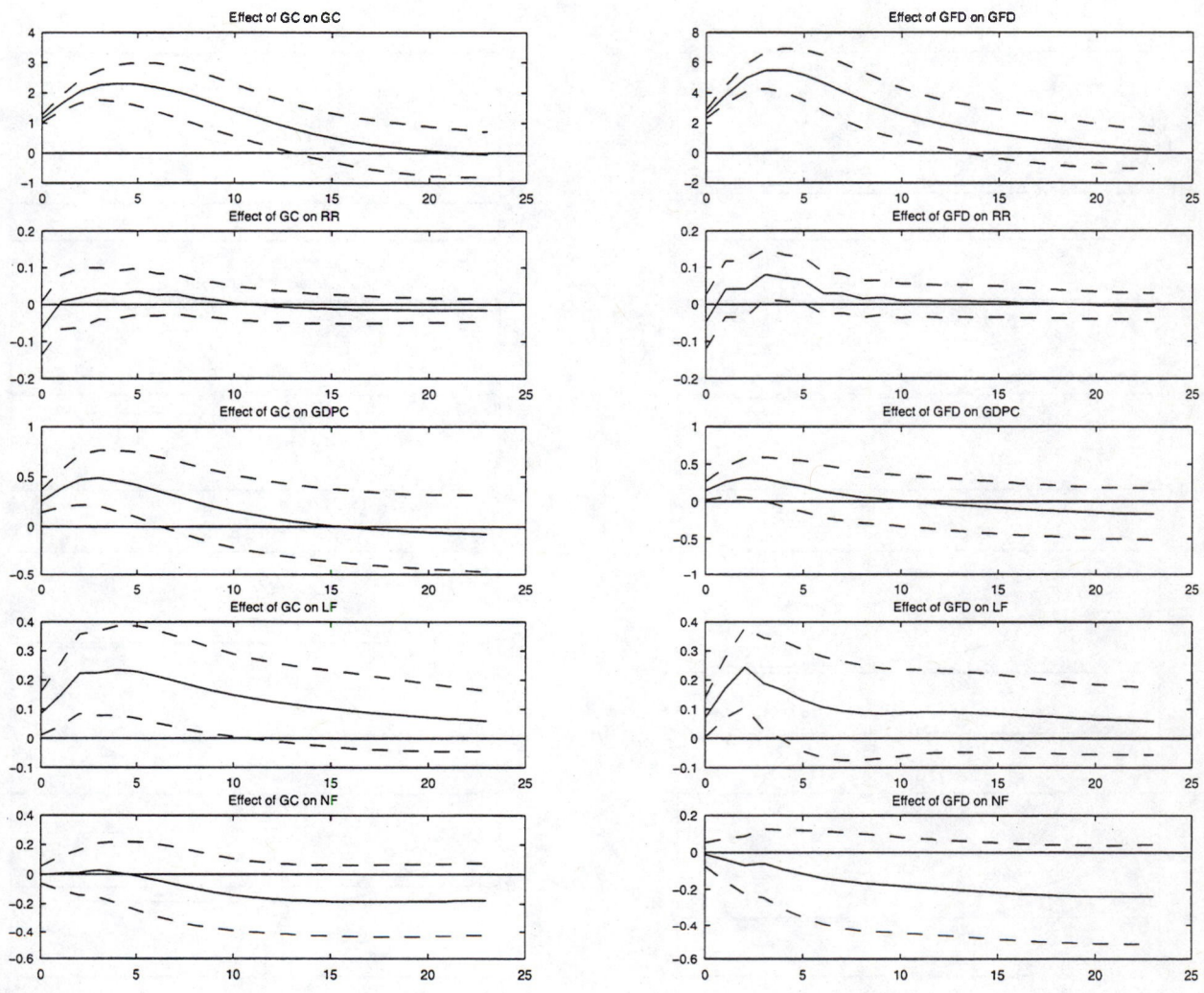


Figure 2: VAR: The Effect of Government Spending Shocks on Employment and Hours Worked per Worker

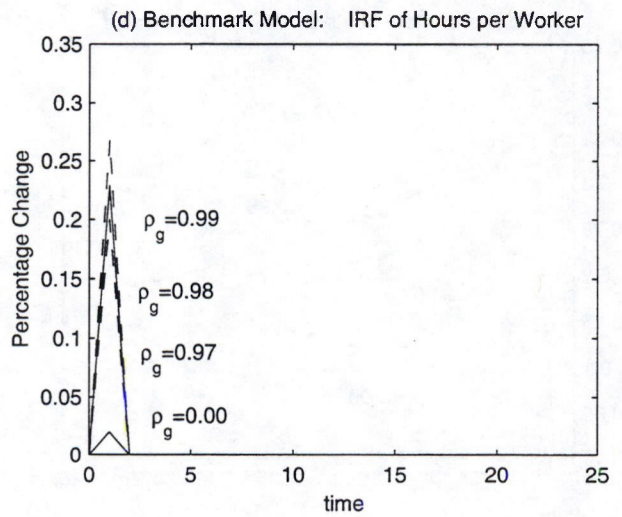
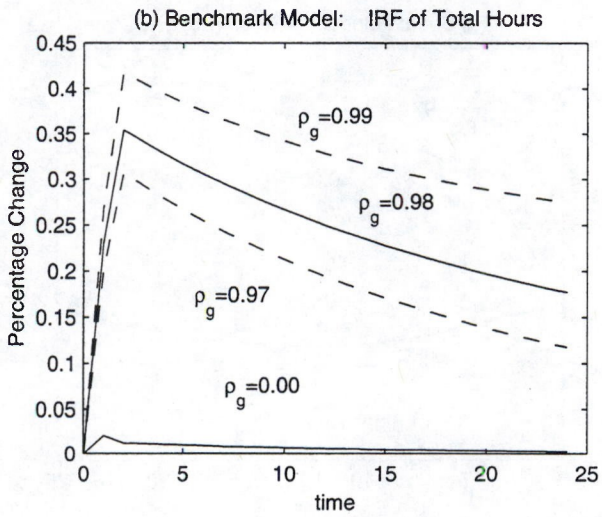
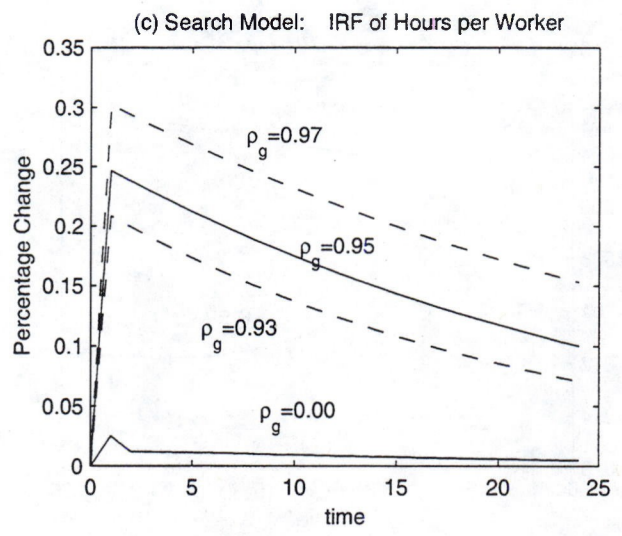
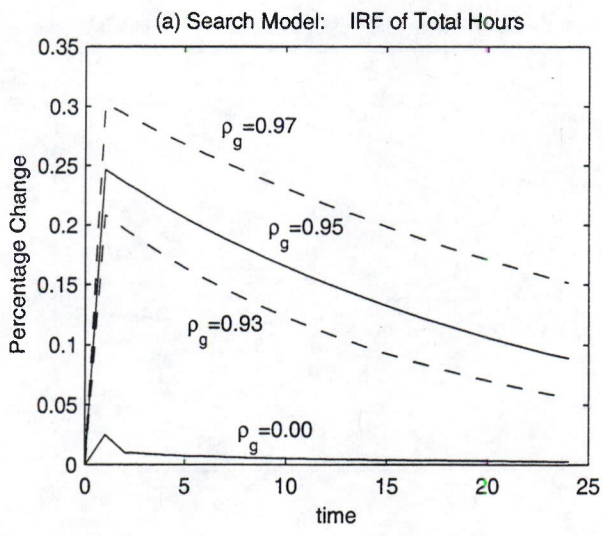


Figure 3: Impulse Response Functions of Total Hours and Hours Worked per Worker

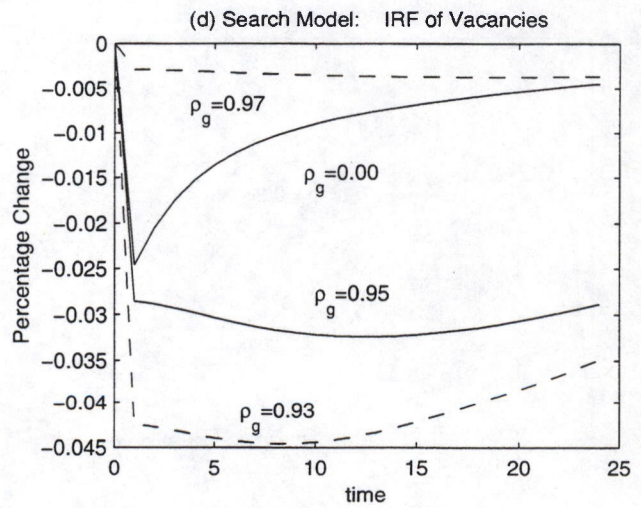
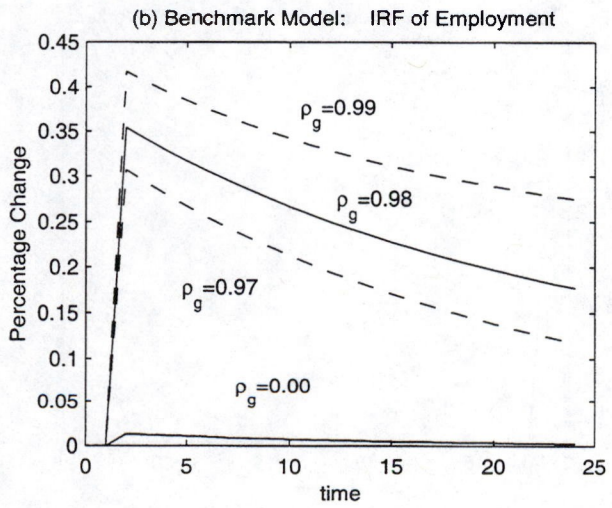
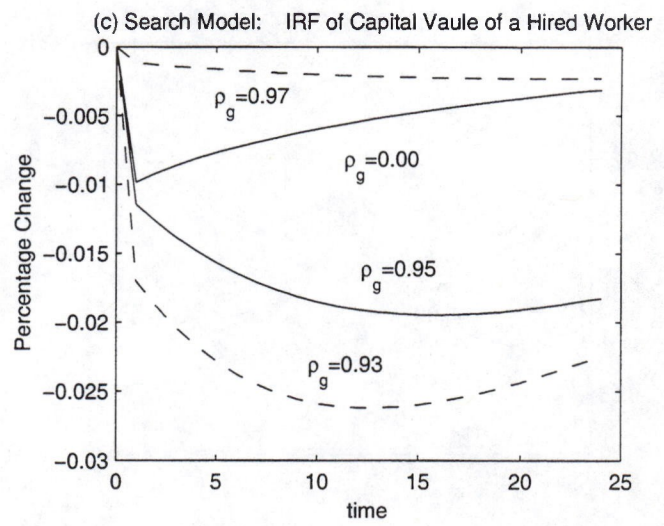
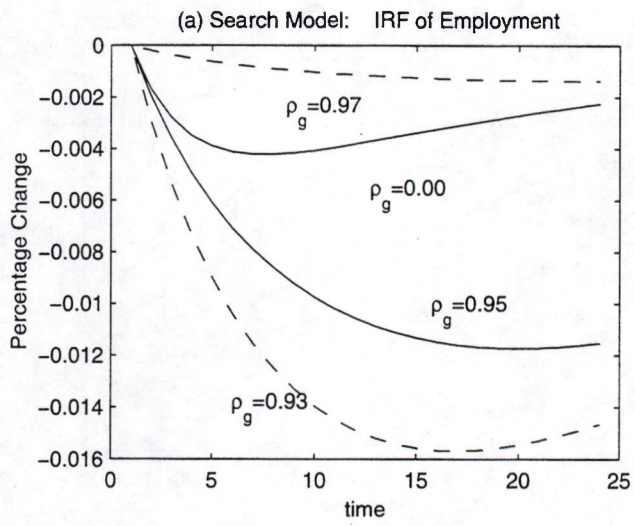


Figure 4: Impulse Response Functions of Employment

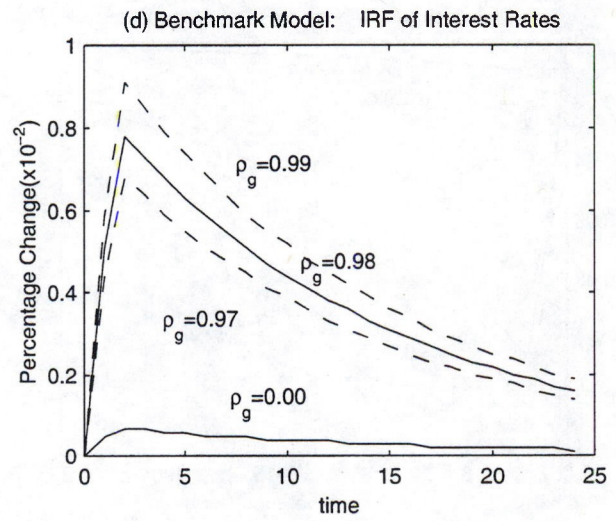
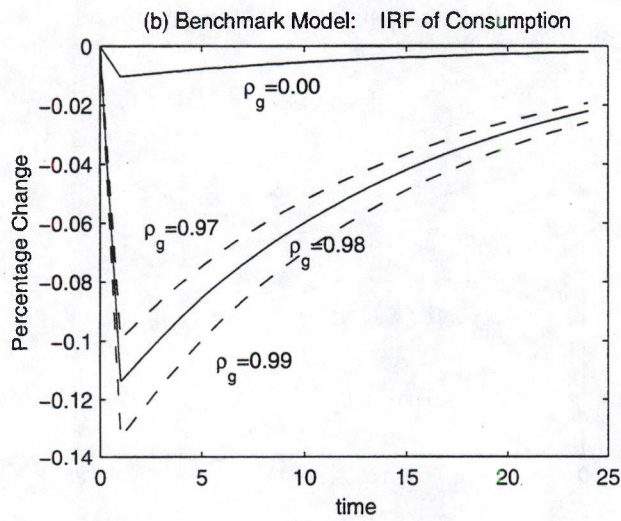
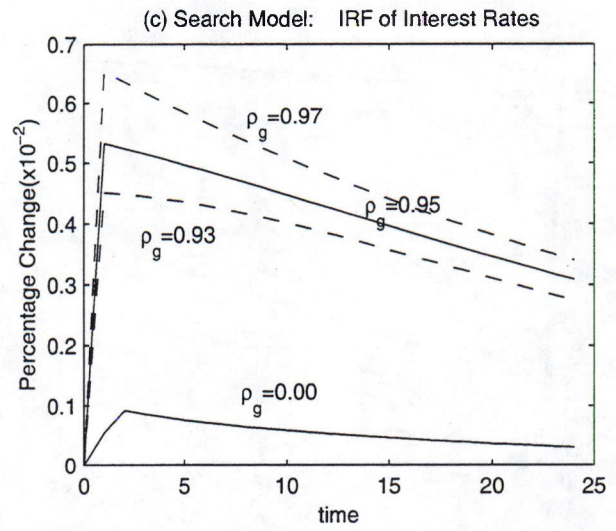
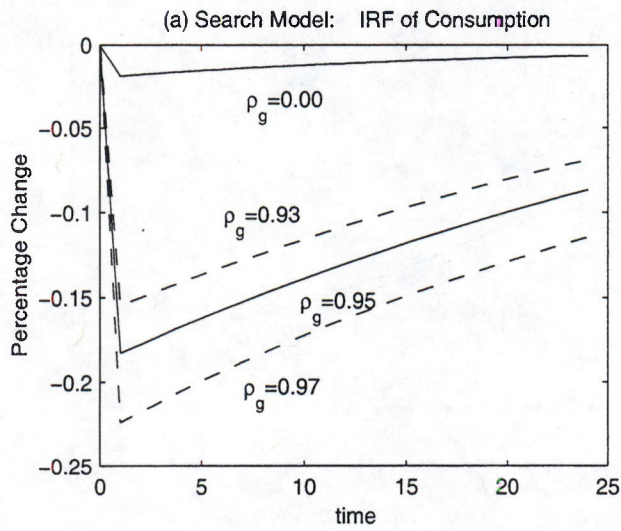


Figure 5: Impulse Response Functions of Consumption and Interest Rates

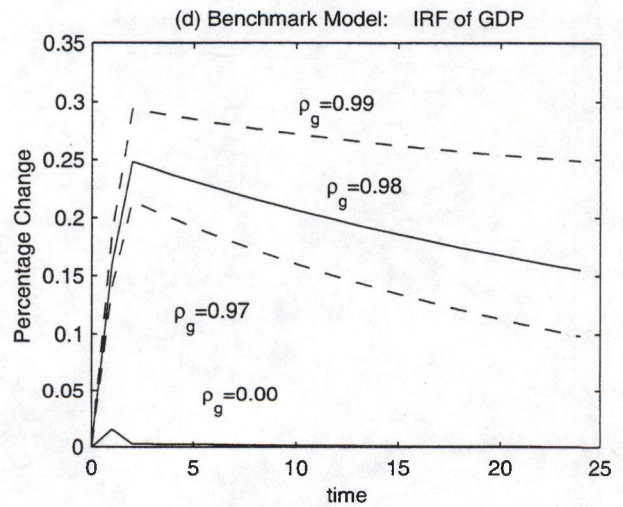
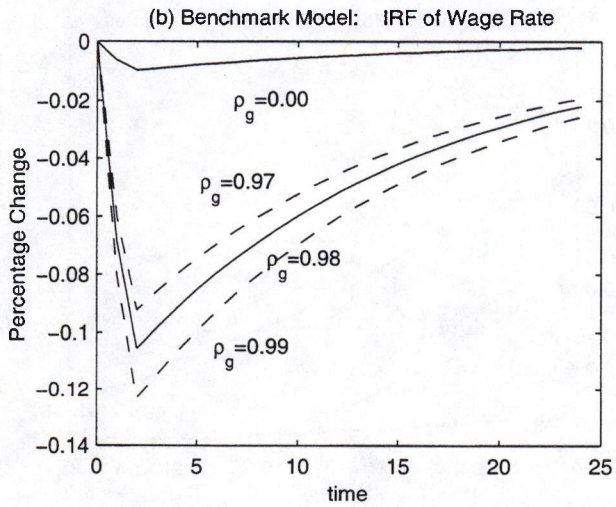
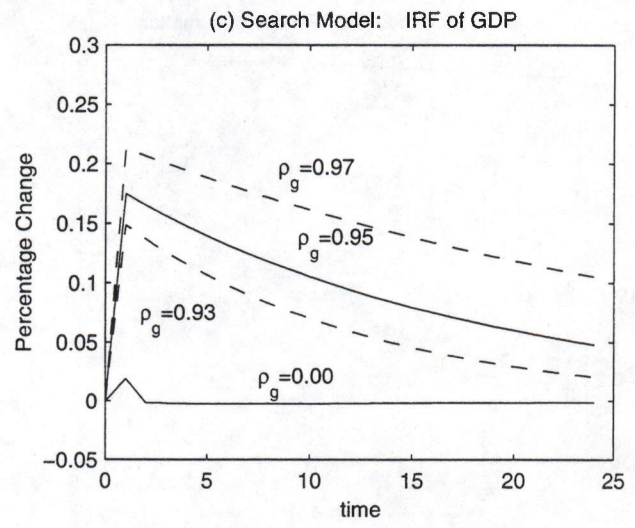
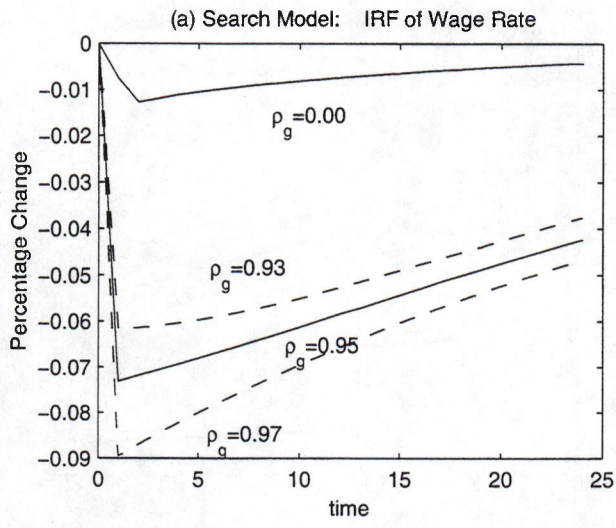


Figure 6: Impulse Response Functions of Wage Rates and GDP

