# DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 98-31


## Aggregate Employment, Real Business Cycles, and Superior Information


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November 1998

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**Cahier de recherche/Working Paper No. 55**

# Aggregate Employment, Real Business Cycles, and Superior Information*

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December 1997

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* The authors are greatful to Gregor Smith for helpful suggestions and Marc Létourneau for his research assistance. Normandin acknowledges financial support from FCAR.

**Abstract:** We test whether dynamic, stochastic, general equilibrium artificial economies associated with several labor market institutions provide an adequate characterization of aggregate employment volatility and dynamics. Our test is robust to possible misspecifications about the information set used by economic agents to forecast future events. Accounting for the agents' superior information, we find that the divisible labor, indivisible labor, and labor hoarding structures replicate employment volatility, in contrast to the nominal wage contracts and labor adjustment costs structures. Also, the labor hoarding structure provides a substantially better account of employment dynamics than the other labor market structures.

Keywords: Labor Market Institutions, Employment Dynamics and Volatility.

JEL Classification Codes: C32, E32, E24

## 1. Introduction

One of the most striking features of aggregate employment behavior is that per capita total hours are volatile and persistent. Unfortunately, Prescott (1986) demonstrates that observed employment is twice as volatile as that predicted by the standard real business cycle (RBC) economy with divisible labor. This finding has inspired a wide research program based on the exploration of market institutions that could explain this volatility. Examples include indivisible labor and nominal wage contracts. More recently, Cogley and Nason (1995) document that actual output dynamics is substantially more persistent then that generated from most RBC economies. This prompted the exploration of market institutions that could explain output dynamics via input dynamics and, in particular, employment dynamics. Examples include labor adjustment costs, labor hoarding, and labor market search.

In the RBC literature, the analysis of employment behavior is based on calibrated dynamic, stochastic, general equilibrium artificial economies. These RBC economies specify both market institutions and law of motions for forcing variables. These specifications are used to extract certain statistics (*e.g.* the volatility of employment). These statistics are then confronted to that found in the data to assess the ability of RBC economies to account for employment behavior. This procedure thus jointly tests the specification of both market institutions and law of motions.

Arguably, the statistics computed from RBC economies may differ from the data, not because the market institutions are inadequately described, but simply because the law of motions are misspecified. These law of motions systematically postulate that the agents' information set includes only the history of forcing variables. This set is extremely restrictive; it seems most inconceivable that agents do not use additional information to improve their forecasts of future forcing variables. In fact, many variables typically excluded from the agents' information set — namely money, interest rates, government expenditures, military spending, oil prices, and political parties in power — Granger-cause one of the key forcing variable — namely technology shocks (Evans 1992; Hall 1988). Omitting the extra information offered by these variables is akin to omitting some forcing variables and may lead to serious mismeasurements of statistics derived from RBC economies (Ingram, Kocherlakota, and Savin 1994).

This agents' superior information problem can be circumvented by applying instrumental variables procedures (Hansen 1982; Hansen and Sargent 1982). These procedures provide consistent estimates of the structural parameters related to the market institutions, even when the law of motions are misspecified. Unfortunately, these methods alone do not permit the computation of the statistics traditionally used in RBC studies. This is because the calculation of these statistics requires a specification of the law of motion that correctly reflects the agents' true information set.

Our paper offers the first formal superior-information-robust test allowing us to verify whether RBC economies adequately characterize employment behavior. This test checks that the statistics generated from RBC economies are in accord with the data. These statistics measure the volatility of employment, which is a standard practice, and also capture the dynamics of employment, which is generally ignored. Employment volatility and dynamics are computed from calibrated values of the structural parameters and estimated values of an augmented law of motion. Following Campbell and Deaton (1989), we show that the augmented law of motion corresponds to a vector autoregressive (VAR) process involving not only forcing variables, but also employment. Under the assumed market institutions and the existence of agents' superior information, employment embodies all relevant information: changes in this variable signal agents' early notice of future movements of forcing variables. This feature is most attractive since it allows us to avoid exhaustively specifying the relevant agents' information set. This procedure also enables us to account for news shocks that can only be observed by agents and not by researchers (Cochrane 1994).

The empirical analysis proceeds as follows. First, we verify the existence of agents' superior information. We find strong support for superior information, that is, employment always significantly Granger-causes forcing variables. Second, we test whether Christiano and Eichenbaum's (1992) RBC economy with divisible labor explains employment behavior. We demonstrate that this benchmark RBC economy reproduces employment volatility, as long as superior information is taken into account. This is in sharp contrast with previous studies, which neglect superior information. However, the benchmark economy fails to provide an adequate characterization of employment dynamics, even when superior information is incorporated. Third, we extend our analysis to search for an RBC economy that replicates both employment volatility and dynamics. To do so, we consider several RBC economies that are differentiated by their labor market institutions. These institutions are nominal wage contracts (Cho 1993; Cho and Cooley 1995), labor adjustment costs (Cogley and Nason 1995), indivisible labor (Hansen 1985; Rogerson 1988), and labor hoarding (Burnside, Eichenbaum, and Rebelo 1993; Burnside and Eichenbaum 1996). Accounting for the agents' superior information, we show that only the indivisible labor and labor hoarding structures replicate employment volatility. We also find that the labor hoarding structure provides a substantially better account of employment dynamics than the other labor market institutions.

The paper is organized as follows. Section 2 uses the benchmark RBC economy to illustrate the difficulties of explaining employment volatility and dynamics when superior information is omitted. Section 3 tests the existence of agents' superior information and introduces this notion to the benchmark economy to assess employment behavior. Section 4 incorporates superior information to various alternative labor market structures to analyze employment behavior. Section 5 concludes.

## 2. Basic Results

This section documents the difficulties of explaining aggregate employment from a benchmark RBC economy. For illustrative purposes, we use Christiano and Eichenbaum's (1992) economic environment with divisible labor, which postulates that individuals may work an intermediate number of hours:

$$\max E_t \sum_{j=0}^{\infty} \beta^j \left[\ln(C_{t+j}) + \eta \ln(T - N_{t+j})\right], \tag{1.1}$$

$$\text{s.t.} \quad C_t + K_{t+1} - (1-\delta)K_t + G_t = Y_t, \tag{1.2}$$

$$Y_t = K_t^{\alpha} \left(Z_t N_t\right)^{1-\alpha}, \tag{1.3}$$

where $E_t$ represents the conditional expectation operator, $T$ is the endowment of time, $N_t$ is hours worked, $C_t$ is consumption, $K_t$ is the capital stock, and $Y_t$ is output. Also, $G_t$ and $Z_t$ correspond to stochastic government expenditures and technology. Equation (1.1) describes the planner's objective, equation (1.2) is the aggregate resource constraint, and equation (1.3) depicts the aggregate production function.

As is standard practice, we apply the method developed in King, Plosser, and Rebelo (1987) to derive forward looking decision rules for hours and capital. This method consists of a log-linear approximation of the first-order conditions, centered on the deterministic steady state. The existence of this steady state is ensured by applying a stationarity inducing transformation. Assuming that government expenditures and technology are difference-stationary and cointegrated, this transformation entails dividing growing variables by the level of technology: $\tilde{C}_t = C_t/Z_t$, $\tilde{K}_{t+1} = K_{t+1}/Z_t$, $\tilde{Y}_t = Y_t/Z_t$, $\tilde{G}_t = G_t/Z_t$, and $\tilde{Z}_t = Z_t/Z_{t-1}$. We then define our measure of aggregate employment as $n_t = \ln(N_t/N)$, adjusted consumption as $c_t = \ln(\tilde{C}_t/\tilde{C})$, adjusted capital stock as $k_t = \ln(\tilde{K}_t/\tilde{K})$, adjusted output as $y_t = \ln(\tilde{Y}_t/\tilde{Y})$, adjusted government expenditures as $g_t = \ln(\tilde{G}_t/\tilde{G})$, and technology growth as $z_t = \ln(\tilde{Z}_t/\tilde{Z})$—where $N$, $\tilde{C}$, $\tilde{K}$, $\tilde{Y}$, $\tilde{G}$, and $\tilde{Z}$ are steady state values.

We finally obtain the following decision rules for employment and adjusted capital:

$$n_t = \theta_{11}k_t + \theta_{12}\mathbf{v}_t + \theta_{13}E_t\sum_{j=1}^{\infty}\lambda^{-j}\mathbf{v}_{t+j}, \tag{2.1}$$

$$k_{t+1} = \frac{1}{1-\theta_{21}L}\left[\theta_{22}\mathbf{v}_t + \theta_{23}E_t\mathbf{v}_{t+1} + \theta_{24}E_t\sum_{j=1}^{\infty}\lambda^{-j}\mathbf{v}_{t+j}\right], \tag{2.2}$$

where $L$ is the lag operator and $\mathbf{v}_t = [z_t, g_t]'$ is a vector of forcing variables.

For convenience, we eliminate adjusted capital by lagging (2.2) and substituting in (2.1) to obtain the modified decision rule for employment:

$$\begin{aligned} n_t &= \theta_{n1}n_{t-1} + \theta_{n2}\mathbf{v}_{t-1} + \theta_{n3}\mathbf{v}_t + \theta_{n4}E_{t-1}\mathbf{v}_t \\ &+ \theta_{n5}E_{t-1}\sum_{j=1}^{\infty}\lambda^{-j}\mathbf{v}_{t+j-1} + \theta_{n6}E_t\sum_{j=1}^{\infty}\lambda^{-j}\mathbf{v}_{t+j}. \end{aligned} \tag{3}$$

Equation (3) provides the main relation that enables us to compute the volatility and the dynamics of employment. To perform those computations, however, (3) must be expressed exclusively in terms of observed variables. This requires the construction of the expectations of future forcing variables. For this purpose, we specify the following process:

$$\begin{pmatrix} z_t \\ g_t \\ n_t \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & \rho & 0 \\ \gamma_{31} & \gamma_{32} & \gamma_{33} \end{pmatrix}\begin{pmatrix} z_{t-1} \\ g_{t-1} \\ n_{t-1} \end{pmatrix} + \begin{pmatrix} u_{zt} \\ u_{gt} \\ u_{nt} \end{pmatrix}, \tag{4}$$

where $\omega_{ij} = E(u_{it}u_{jt})$, for $i$ and $j = z$, $g$, and $n$. The last equation of (4) corresponds to an unrestricted reduced form for employment. The first two equations represent the law of motion for forcing variables. The expectations of future forcing variables constructed from (4) are substituted in equation (3) to yield the restricted process:[1]

$$\begin{pmatrix} z_t \\ g_t \\ n_t \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & \rho & 0 \\ 0 & \phi & \theta_{n1} \end{pmatrix}\begin{pmatrix} z_{t-1} \\ g_{t-1} \\ n_{t-1} \end{pmatrix} + \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ \theta_{n3,1} & \psi & 0 \end{pmatrix}\begin{pmatrix} u_{zt} \\ u_{gt} \\ u_{nt} \end{pmatrix}, \tag{5}$$

[1] The process (4) implies that the constructed expectations derived from the law of motion and the unrestricted reduced form are similar to that obtained by using exclusively the law of motion. However, including the unrestricted reduced form in (4) will prove to be useful for our analysis.

where $\theta_{n3,1}$ is the first element of $\theta_{n3}$, and $\phi$ and $\psi$ are constructed from $\rho$, $\lambda$, and $\theta_{n1}$ to $\theta_{n6}$. The last equation of (5) is the restricted reduced form for employment. The first and second equations are identical to (4) and describe the law of motion for forcing variables.

Finally, we assign values to all parameters. We follow Christiano and Eichenbaum (1992) and set $\beta = 1.03^{-0.25}$, $\eta = 3.92$, $\delta = 0.021$, $\alpha = 0.344$, and $T = 1369$. We use a sample of U.S. seasonally adjusted quarterly data over the 1960:II to 1993:IV period to set $\tilde{Z} = 1.0031$ and $\tilde{G}/\tilde{Y} = 0.125$ (see the Data Appendix). These parameter values are used to compute $\lambda$ and $\theta_{n1}$ to $\theta_{n6}$. We also apply ordinary least squares (OLS) to estimate the parameters in (4). Note that the restricted process (5) indicates that $\gamma_{31} = 0$ and $\gamma_{33} = \theta_{n1}$, such that only $\rho$, $\gamma_{32}$, and the $\omega_{ij}$'s remain to be estimated. This estimation yields $\rho = 0.953$, $\gamma_{32} = -0.019$, $\omega_{zz} = 0.000151$, $\omega_{gg} = 0.000759$, $\omega_{nn} = 0.00007$, $\omega_{zg} = -0.000113$, $\omega_{nz} = 0.00002$, and $\omega_{ng} = -0.00002$.[2]

Table 1 presents several measures of employment volatility. These measures are the standard deviation of employment, $\sigma_n$, the standard deviation of changes in employment, $\sigma_{\Delta n}$, and the ratio of the standard deviations of changes in employment to growth in output, $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$.[3] For observed volatility, these measures are obtained from sample estimates and from the unrestricted reduced form for employment described in (4). For predicted volatility, all three measures are calculated from (5).[4] Finally, for each measure, we test that the ratio of predicted to observed volatility is unity using a $\chi^2(1)$ distributed

[2] Christiano and Eichenbaum's (1992) calibration of the law of motion for forcing variables is $\rho$=0.96, $\omega_{zz}$=0.000324, $\omega_{gg}$=0.0004, $\omega_{zg}$=0.0. They also find $\tilde{Z}$=1.004, and $\tilde{G}/\tilde{Y}$=0.177. Using these values, however, does not alter any of our conclusions.

[3] Augmented Dickey-Fuller tests reject the null hypothesis of nonstationarity for employment and output growth. This ensures that all three measures of volatility are valid.

[4] For $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$, the predicted volatility of output growth is computed similarly to that of employment changes. More precisely, we use a process, that is similar in form to (5), describing the restricted reduced for adjusted output and the law of motion. Then, we use the identity $\Delta \ln(Y_t)$=$\Delta y_t$+$z_t$+$\ln(\tilde{Z})$ to recover the standard deviations of output growth.

statistic. To compute the ratio and the statistic, we use the observed volatility obtained from the process (4). Accordingly, the test statistic accounts for the uncertainty associated with the estimated parameters in (4).

A comparison of observed and predicted employment volatility reveals that historical employment is excessively volatile. For example, the value of $\sigma_n$ found in the data is between 3.529 and 3.681 percent. As expected, both values are close. In contrast, the value generated by the restricted reduced form is only 1.505 percent, such that the ratio ($p$-value) of predicted to observed volatility is 40.9 percent (0.000). This ratio is significantly different from unity. Also, the ratio ($p$-value) of predicted to observed volatility is 54.2 percent (0.000) for $\sigma_{\Delta n}$ and 47.5 percent (0.000) for $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$. Both ratios are significantly different from unity.

Figure 1 displays employment dynamics. Panel A presents the dynamic responses of employment to technology growth and government expenditures growth shocks. Observed responses are computed from the process (4) and predicted responses are generated from (5). Panel B reports the $p$-values of a $\chi^2(1)$ statistic testing that the difference between observed and predicted responses for each period is null—where this procedure accounts for the uncertainty associated with the estimated parameters in (4).

A comparison of observed and predicted responses indicates that (5) fails to predict actual employment dynamics. First, following a positive technology growth shock, actual employment initially declines, and then gradually returns to the steady state. In contrast, predicted employment increases at impact and then decays. Accordingly, the observed and predicted responses are statistically different at the 5 percent level for the first 4 years after the shock. Second, following a positive government expenditures growth shock, actual employment also initially declines, but this reduction continues before a gradual return to the steady state. Predicted employment, however, peaks at impact and then declines. The observed and predicted responses significantly differ at the 5 percent level for each period.

To summarize, we have illustrated two difficulties related to employment behavior.

First, the predicted employment volatility is significantly and substantially smaller than that found in the data. This issue has been widely acknowledged in the literature and has motivated a large research program. Second, predicted and observed employment dynamics are considerably different. This parallels similar findings recently discussed for output dynamics. Admittedly, these results suggest that the economic environment described by the modified decision rule (3) and the law of motion described in (4) provides an inadequate characterization of employment behavior.

## 3. Superior Information

The findings reported in the previous section are derived under the assumption that the law of motion for forcing variables is adequately specified by (4). This process postulates that the information set used by economic agents to forecast future forcing variables includes exclusively the history of forcing variables. This set is extremely restrictive: it seems most implausible that agents do not possess any extra information that help forecast forcing variables. If agents exploit this extra information, they must forecast using a different law of motion than (4). This alternative law of motion is augmented by agents' superior information.

It could then be argued that misspecifications of the law of motion (4) imply inadequate employment behavior, even when the modified decision rule (3) is valid. More precisely, the forecasts obtained from (4) may substantially differ from that induced by the agents' augmented law of motion. Substituting the inadequate forecasts in (3) may underestimate employment volatility and underpredict the persistence of employment dynamics. Clearly, omitting the agents' superior information may lead to serious mismeasurements of employment volatility and dynamics.

To circumvent this problem, we introduce the notion of superior information to the dynamic general equilibrium framework using Campbell and Deaton's (1989) tools. We assume that the modified decision rule (3) is valid, so that agents reveal their expectations of future forcing variables through their employment decisions. Accordingly, the incorporation of current employment in the law of motion for forcing variables ensures that any extra information is fully captured. This feature is most attractive since it allows us to avoid the difficult, perhaps impossible, task of specifying the exhaustive list of forcing variables to be included in the relevant information set.

Our analysis is performed using $\tau$-order VAR processes. For exposition purposes, consider the first-order unrestricted VAR process:

$$\begin{pmatrix} z_t \\ g_t \\ n_t \end{pmatrix} = \begin{pmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} \\ \gamma_{21} & \gamma_{22} & \gamma_{23} \\ \gamma_{31} & \gamma_{32} & \gamma_{33} \end{pmatrix} \begin{pmatrix} z_{t-1} \\ g_{t-1} \\ n_{t-1} \end{pmatrix} + \begin{pmatrix} u_{zt} \\ u_{gt} \\ u_{nt} \end{pmatrix},$$

or

$$\mathbf{x}_t = \Gamma \mathbf{x}_{t-1} + \mathbf{u}_t, \tag{6}$$

where $\Omega = E(\mathbf{u}_t \mathbf{u}_t')$. The last equation of the system described by (6) corresponds to the unrestricted reduced form for employment, given the augmented law of motion for forcing variables. The first and second equations of the system describe this law. Unlike (4), this specification allows the possibility of observing a negative feedback from lagged employment to technology growth ($\gamma_{13} < 0$) and a positive one from lagged employment to adjusted government expenditures ($\gamma_{23} > 0$). These feedbacks are predicted by (3) and the existence of superior information. In particular, the calibrated vector $\theta_{n6} = [-0.627, 0.010]'$ implies that agents signal early notice of future decreases of technology growth and future increases of adjusted government expenditures by raising current employment.

Table 2 reports OLS estimates of the relevant feedbacks and Granger-causality tests for the lag structures $\tau = 1$, 2, 4, and 8. The lag length $\tau = 1$ is prescribed by the Schwarz criterion, while $\tau = 2$ and $\tau = 8$ are selected by the Akaike criterion and the likelihood ratio test. For $\tau = 1$, the estimates ($p$-values) of feedbacks from employment to technology growth and adjusted government expenditures are -0.073 (0.017) and 0.129 (0.074). Also, the $\chi^2(2)$ statistic ($p$-value) associated with the joint test that current employment contains no additional information useful to predict technology growth and adjusted government expenditures is 7.159 (0.028). Estimates at alternative lag lengths exhibit similar signs and significance levels. Thus, these findings are consistent with the theoretical feedbacks induced by (3) and strongly support the existence of superior information.

As explained previously, we express the modified decision rule (3) exclusively in terms of observed variables. To this end, we use (6) to solve for the expectations of future forcing variables. Substituting these expectations in (3) yields the restricted VAR process:

$$\begin{pmatrix} z_t \\ g_t \\ n_t \end{pmatrix} = \begin{pmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} \\ \gamma_{21} & \gamma_{22} & \gamma_{23} \\ \phi_{31} & \phi_{32} & \phi_{33} \end{pmatrix} \begin{pmatrix} z_{t-1} \\ g_{t-1} \\ n_{t-1} \end{pmatrix} + \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ \psi_{31} & \psi_{32} & \psi_{33} \end{pmatrix} \begin{pmatrix} u_{zt} \\ u_{gt} \\ u_{nt} \end{pmatrix},$$

or

$$\mathbf{x}_t = \Phi\,\mathbf{x}_{t-1} + \Psi\mathbf{u}_t, \tag{7}$$

where $\Phi$ and $\Psi$ are constructed from the parameters in (6), $\Gamma$, and the parameters in (3), $\lambda$ and $\theta_{n1}$ to $\theta_{n6}$. The last equation of (7) is the restricted reduced form for employment. The first and second equations are identical to that defined in (6), since they describe the augmented law of motion for forcing variables.

Table 3 reports our three measures of employment volatility. For observed volatility, the measures are computed from the unconditional second moments of $\mathbf{x}_t$ derived from the unrestricted VAR process (6):

$$\Sigma^o = \Gamma\Sigma^o\Gamma' + \Omega. \tag{8}$$

For predicted volatility, the measures are recovered from the restricted VAR process (7):

$$\Sigma^p = \Phi\Sigma^p\Phi' + \Psi\Omega\Psi'. \tag{9}$$

The validity of the modified decision rule (3) with superior information can be tested by formally verifying whether the observed and predicted employment volatility are close. For each measure, we test that the ratio of predicted to observed volatility is unity using a $\chi^2(1)$ distributed statistic. This procedure accounts for the uncertainty associated with the unrestricted VAR parameters and is thus robust to the existence of superior information.

A comparison of observed and predicted employment volatility reveals that the economic environment jointly described by the modified decision rule (3) and the unrestricted VAR process (6) resolves the puzzling excess volatility of employment. For $\tau = 1$, the value of $\sigma_n$ derived from the unrestricted VAR process is 3.726 percent and the value generated from the restricted VAR process is 1.975 percent. Accordingly, the ratio ($p$-value) of predicted to observed volatility is 53.0 percent (0.014). This ratio is insignificantly different from unity at the 1 percent level and accounts for more of the fluctuations in actual employment than the 40.9 percent found when superior information is neglected. For $\sigma_{\Delta n}$ and $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$, the ratios ($p$-values) are 93.5 percent (0.753) and 70.4 percent (0.062).[5] These ratios are insignificantly different from unity at the 5 percent level, and are substantially larger than the 54.2 percent and 47.5 percent values found without superior information. For alternative lag lengths, the ratios of predicted to observed volatility associated with each measure are always insignificantly different from unity at all conventional levels.

Figure 2 displays employment dynamics. Panel A presents the dynamic responses of employment to various shocks. Panel B reports the $p$-values of the $\chi^2(1)$ statistic testing that the difference between observed and predicted responses for each period is null — where this procedure accounts for the uncertainty associated with the unrestricted VAR parameters. For observed dynamics, the period $j$ responses are computed from the

[5] For $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$, the predicted volatility of output growth is computed similarly to that of employment. More specifically, we use a restricted VAR process obtained from a modified decision rule and an unrestricted VAR process for adjusted output that are similar in form to (3) and (6). We then use the identity $\Delta \ln(Y_t) = \Delta y_t + z_t + \ln(\tilde{Z})$ to recover the standard deviations of output growth.

unrestricted VAR process to yield:

$$\mathrm{R}_j^o = \Gamma^j \Lambda, \tag{10}$$

where $\Omega = \Lambda\Lambda'$ and $\Lambda$ is a lower triangular matrix with positive elements on the diagonal. For predicted dynamics, the responses are calculated from the restricted VAR process to yield:

$$\mathrm{R}_j^p = \Phi^j \Psi \Lambda. \tag{11}$$

Equations (10) and (11) permit the extraction of actual and predicted responses of employment to technology growth, government expenditures growth, and employment shocks. Given the VAR ordering $\mathbf{x}_t = [z_t, g_t, n_t]'$, these shocks correspond to the orthogonal innovations $\mathbf{e}_t = [e_{zt}, e_{gt}, e_{nt}]'$, where $\mathbf{e}_t = \Lambda^{-1}\mathbf{u}_t$. In particular, the technology growth shock is measured by a positive one standard deviation in $e_{zt}$. The government expenditures growth shock is captured as the sum of a positive one standard deviation in $e_{zt}$ and in $e_{gt}$.[6] . The employment shock is a positive one standard deviation in $e_{nt}$. This shock summarizes all the news contained in the agents' extra information. Of course, the employment shock is non-existent when superior information is omitted.

A comparison of observed and predicted employment dynamics indicates that the restricted VAR process with superior information generally fails to replicate the persistence of actual responses. For $\tau = 1$, the actual response of employment to a technology growth shock is an initial decline, followed by a sharp increase and a gradual return to the steady state. In contrast, the predicted response reaches a peak at impact and rapidly decays. Accordingly, the predicted and observed responses are statistically different at the 5 percent level for more than a year. Also, the predicted response is almost identical to that found when superior information is omitted. The actual response to a shock to government expenditures growth is an initial decline, followed by a substantial increase and a slight fall before a return to the steady state. The predicted response is positive and humpshaped.

[6] This is consistent with the identity $\Delta \ln(G_t) = \Delta g_t + z_t + \ln(\tilde{Z})$

The observed and the predicted responses thus differ significantly after roughly a year. Moreover, the predicted responses derived with and without superior information display systematically the wrong sign. Finally, the actual response to an employment shock is an initial increase, followed by a slow decay. The predicted response is less persistent and significantly smaller for the first 5 years. The findings just reported are quite robust to the choice of the lag structure.

To summarize, we have verified two properties of employment behavior by performing tests that are robust to misspecifications of the law of motion for forcing variables. First, employment is not excessively volatile when we account for superior information. This contrasts sharply with results obtained when superior information is ignored. Second, employment responds anomalously to shocks even when we account for superior information. These responses generally accord with the dynamic responses obtained when superior information is neglected. These last results suggest that misspecifications of the law of motion are not entirely responsible for the inadequacy of employment behavior.

## 4. Extensions

The findings just reported suggest that the modified decision rule for employment derived under a divisible labor structure should be reconsidered. In this spirit, other structures have been investigated recently. We extend our analysis to some of these. In particular, we assess the following popular structures: indivisible labor (Hansen 1985; Rogerson 1988), nominal wage contracts (Cho 1993; Cooley and Cho 1995), labor adjustment costs (Cogley and Nason 1995), and labor hoarding (Burnside, Eichenbaum, and Rebelo 1993; Burnside and Eichenbaum 1996). For simplicity, the different labor market institutions are grafted on our benchmark framework. Details for these structures and their calibration are presented in the Technical Appendix.

Table 4 presents ratios ($p$-values) of predicted to observed employment volatility for the divisible labor structure and each of the alternative labor market structure. Figures 3 to

6 display predicted and observed employment responses ($p$-values). The ratios, responses, and tests are computed from VAR processes with lag lengths $\tau = 2$. This is because, first, the modified decision rule under both the labor adjustment costs and labor hoarding structures requires $\tau \geq 2$ (see the Technical Appendix) and, second, the results are robust to the choice of $\tau$. Finally, the ratios, responses, and tests account for superior information, as previously explained.

For one-period nominal wage contracts, workers and firms agree on a preset nominal wage that clears the labor market in expectation. Employment is then determined by firms. In this context, labor market adjustments are entirely sustained by employment. Also, the labor market is subjected to an additional shock, namely a monetary shock.[7] These elements should translate into larger employment fluctuations. This intuition is confirmed empirically: predicted employment volatility always statistically overstates observed employment volatility, regardless of the measure.[8] Also, employment responses should be larger, because only employment adjusts. This is generally verified empirically.[9] Furthermore, predicted responses often display the wrong sign and are statistically different from observed responses.

For labor adjustment costs, firms find it costly to vary employment. The obvious implication is that employment changes are sluggish. This should translate into a smaller predicted employment volatility, which is mainly confirmed empirically. Notably, predicted employment volatility statistically matches actual employment volatility for $\sigma_n$ and $\sigma_{\Delta n}$, but not for $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$. This sluggishness should also add persistence to employment fluctuations. This is verified empirically: predicted employment responses slowly decay.

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7 Accordingly, the unrestricted VAR process uses $\mathbf{x}_t = [z_t, g_t, \pi_t, n_t]'$, where $\pi_t$ is adjusted money growth.

8 We do not consider multi-period contracts, because Cho and Cooley (1995) document that increasing the contract length further increases the volatility of employment.

9 Responses to the money growth shock are not presented, because money growth innovations only have a contemporaneous effect on employment for a one-period contract structure.

Also, although the predicted response to a technology growth shock almost always statistically replicates the observed response, the predicted responses to government expenditures growth and employment shocks significantly differ from observed responses for at least the first three years.

For indivisible labor, individuals can either work some given positive number of hours or not at all. This should imply larger fluctuations in employment. This rationalizes the empirical fact that the predicted and actual employment volatility are insignificantly different — whatever the measure used. Intuitively, however, this indivisibility should not ensure more persistence to employment responses. Empirically, predicted employment responses generally die off very rapidly. Also, although the predicted response to a technology growth shock almost always statistically replicates the observed response, the predicted responses to employment and government expenditures growth shocks significantly differ from observed responses after roughly 1 and 2 years respectively.

For labor hoarding, labor is indivisible, employment is preset, and effort is adjusted to ensure that the labor market clears. In this context, workers and firms choose next period's employment, which induces information costs: employment responds to shocks with a period delay. Although these costs should reduce employment fluctuations, the indivisibility has the opposite effect. Empirically, these elements generate a predicted employment volatility that statistically matches the observed one for each measure. The information costs should also make employment changes more persistent, which is verified empirically.[10] Moreover, predicted and observed responses to both technology growth and government expenditures growth shocks are extremely similar and insignificantly different. Finally, although the predicted and actual responses are sometimes different, they are remarkably close.

To summarize, we have tested the validity of four popular alternative descriptions

[10] For these computations, the unrestricted VAR process uses $\mathbf{x}_t = [z_t, g_t, n_{t+1}]'$, because the relevant modified decision rule is for $n_{t+1}$. This accounts for differences in the actual responses of employment.

of labor market institutions. First, the indivisible labor and labor hoarding structures always replicate employment volatility, in contrast to the nominal wage contracts and labor adjustment costs structures. Second, the labor hoarding structure provides a substantially better account of employment dynamics than the other labor market structures. Overall, these results suggest that the labor hoarding structure with superior information offers an adequate characterization of employment behavior.

## 5. Conclusion

In this paper, we test whether dynamic, stochastic, general equilibrium artificial economies associated with several labor market institutions provide an adequate explanation for aggregate employment behavior. In our analysis, employment behavior is summarized by its volatility and its dynamics. Our testing procedure is robust to possible misspecifications about the information set used by economic agents to forecast future events. That is, our test is based on a law of motion augmented by agents' superior information.

Empirically, we find strong support for agents' superior information. We show that ignoring the extra information leads to serious mismeasurements of employment volatility. Accounting for the agents' additional information, we find that the divisible labor, indivisible labor, and labor hoarding structures replicate employment volatility. Also, the labor hoarding structure provides a substantially better explanation of employment dynamics than the other labor market structures. These results are robust to the choice of the lag length for the augmented law of motion for forcing variables. Overall, these findings reveal that the labor market institutions described by labor hoarding with agents' superior information offer the best characterization of employment behavior.

The notion of agents' superior information was documented by intentionally focusing on one of the central RBC research programs, which is devoted to the understanding of employment behavior. Given that this notion is empirically important, a natural extension is the incorporation of agents' superior information to assess the joint behavior of various macroeconomic time series. Interestingly, the method presented in this paper can be easily applied to test whether predicted volatility, co-volatility, dynamics, and forecastable movements match that found in the data.

## Technical Appendix

This appendix describes the various structures used in Section 4.

*Nominal Wage Contract*

The economic environment is:

$$E_t \sum_{j=0}^{\infty} \beta^j \left[\ln(C_{t+j}) + \eta \ln(T - N_{t+j})\right], \tag{A.1}$$

$$C_t + K_{t+1} - (1-\delta)K_t + G_t = Y_t, \tag{A.2}$$

$$Y_t = K_t^{\alpha} \left(Z_t N_t\right)^{1-\alpha}, \tag{A.3}$$

$$\ln(W_t^c) = E_{t-1}\Big[\ln\left((1-\alpha)P_t Y_t / N_t\right)\Big], \tag{A.4}$$

$$W_t^c = (1-\alpha)P_t Y_t / N_t, \tag{A.5}$$

$$P_t C_t = M_t. \tag{A.6}$$

Equations (A.1), (A.2), and (A.3) describe preferences, the aggregate resource constraint, and the aggregate production function. Equation (A.4) defines the preset contract wage, $W_t^c$. In this environment, firms and workers agree on a preset wage that clears the labor market in expectations, where $P_t$ is the aggregate price level. Equation (A.5) ensures that employment is demand determined by the firm via the marginal product of labor. Finally, equation (A.6) introduces money, $M_t$, which is assumed stochastic.

The one-period contract and the divisible labor structures share the same steady state. Accordingly, and because contracts have a one period length, the modified decision rule (3) and equation (A.6) are used to construct the new modified decision rule for employment:

$$\begin{aligned} n_t &= \theta_{n1} n_{t-1} + \theta_{n2} \mathbf{v}_{t-1} + \theta_{n3} E_{t-1} \mathbf{v}_t + \theta_{n4} E_{t-1} \sum_{j=1}^{\infty} \lambda^{-j} \mathbf{v}_{t+j} \\ &+ (E_t - E_{t-1}) \left[\theta_{n5} \mathbf{v}_t + \theta_{n6} \mathbf{v}_{t+1} + \theta_{n7} \sum_{j=1}^{\infty} \lambda^{-j} \mathbf{v}_{t+j} + \theta_{n8} \pi_t\right], \end{aligned}$$

where $\mathbf{v}_t = [z_t, g_t]'$, $\pi_t = \ln(\tilde{M}_t/\tilde{M})$, and $\tilde{M}_t = (M_t/M_{t-1})(Z_{t-1}/Z_t)$. For our computations, we calibrate the nominal wage contract economy as in the divisible labor economy. Also, the analysis can be performed from $\tau$-order VAR processes with $\mathbf{x}_t = [z_t, g_t, \pi_t, n_t]'$ and

$\tau \geq 1$. In the estimation of these processes, zero-restrictions are imposed on lagged adjusted money coefficients, $\pi_t$, to ensure that the steady state with nominal wage contract is identical to that with divisible labor.

*Labor Adjustment Costs*

The economic environment is:

$$E_t \sum_{j=0}^{\infty} \beta^j \left[\ln(C_{t+j}) + \eta \ln(T - N_{t+j})\right], \tag{A.7}$$

$$C_t + K_{t+1} - (1-\delta)K_t + G_t = Y_t, \tag{A.8}$$

$$Y_t = (K_t)^{\alpha}(N_t Z_t)^{1-\alpha} \exp\left[-\frac{\xi}{2}\left(\frac{\Delta N_t}{N_{t-1}}\right)^2\right]. \tag{A.9}$$

Equations (A.7), (A.8), and (A.9) describe preferences, the aggregate resource constraint, and the aggregate production function. The extra term in the production function denotes the adjustment cost.

This adjustment cost implies that past employment is a state variable. This is responsible for a modified decision rule of the form:

$$\begin{aligned} n_t = {} & \theta_{n1} n_{t-1} + \theta_{n2} n_{t-2} + \theta_{n3} \mathbf{v}_{t-1} + \theta_{n3} \mathbf{v}_t + \theta_{n4} E_{t-1} \mathbf{v}_t \\ & + \theta_{n5} E_t \mathbf{v}_{t+1} + \theta_{n6} E_{t-1} \sum_{j=1}^{\infty} \lambda^{-j} \mathbf{v}_{t+j-1} + \theta_{n7} E_t \sum_{j=1}^{\infty} \lambda^{-j} \mathbf{v}_{t+j}, \end{aligned}$$

where $\mathbf{v}_t = [z_t, g_t]'$. For our computations, we retain the calibration of the divisible labor economy, except for $\xi = 0.36$ (Cogley and Nason 1995). Also, the analysis can be based on $\tau$-order VAR processes with $\mathbf{x}_t = [z_t, g_t, n_t]'$ and $\tau \geq 2$. These lag structures are required because the modified decision rule involves two lags of employment.

*Indivisible Labor*

The economic environment is:

$$E_t \sum_{j=0}^{\infty} \beta^j \left[\ln(C_{t+j}) + \eta (T - N_{t+j})\right], \tag{A.10}$$

$$C_t + K_{t+1} - (1-\delta)K_t + G_t = Y_t, \tag{A.11}$$

$$Y_t = K_t^{\alpha} \left(Z_t N_t\right)^{1-\alpha}. \tag{A.12}$$

Equations (A.10), (A.11), and (A.12) describe preferences, aggregate resource constraint, and aggregate production function.

The modified decision rule is:

$$n_t = \theta_{n1} n_{t-1} + \theta_{n2} \mathbf{v}_{t-1} + \theta_{n3} \mathbf{v}_t + \theta_{n4} E_{t-1} \mathbf{v}_t$$
$$+ \theta_{n5} E_{t-1} \sum_{j=1}^{\infty} \lambda^{-j} \mathbf{v}_{t+j-1} + \theta_{n6} E_t \sum_{j=1}^{\infty} \lambda^{-j} \mathbf{v}_{t+j},$$

where $\mathbf{v}_t = [z_t, g_t]'$. We use the calibration of the divisible labor structure, except for $\eta = 0.00374$ (Christiano and Eichenbaum 1992). Also, the analysis can be performed from $\tau$-order VAR processes with $\mathbf{x}_t = [z_t, g_t, n_t]'$ and $\tau \geq 1$.

*Labor Hoarding*

The economic environment is:

$$E_t \sum_{j=0}^{\infty} \beta^j \left[ \ln(C_{t+j}) + \eta N_{t+j} \ln(T - \zeta - W_{t+j} f) + \eta (1 - N_{t+j}) \ln(T) \right], \tag{A.13}$$

$$C_t + K_{t+1} - (1 - \delta) K_t + G_t = Y_t, \tag{A.14}$$

$$Y_t = K_t^{\alpha} (Z_t N_t W_t f)^{1-\alpha}, \tag{A.15}$$

where $W_t$ denotes effort, $f$ is the fixed work shift length, and $\zeta$ is a fixed cost. Equations (A.13), (A.14), and (A.15) describe preferences, resource constraint, and production function. In this environment, employment is preset, but effort adjusts to ensure that the labor market clears.

The main implications are that the relevant modified decision rule is for next period's employment, and that current employment is a state variable. This yields:

$$n_{t+1} = \theta_{n1} n_t + \theta_{n2} n_{t-1} + \theta_{n3} \mathbf{v}_{t-1} + \theta_{n3} \mathbf{v}_t + \theta_{n4} E_{t-1} \mathbf{v}_t$$
$$+ \theta_{n5} E_t \mathbf{v}_{t+1} + \theta_{n6} E_{t-1} \sum_{j=1}^{\infty} \lambda^{-j} \mathbf{v}_{t+j-1} + \theta_{n7} E_t \sum_{j=1}^{\infty} \lambda^{-j} \mathbf{v}_{t+j},$$

where $\mathbf{v}_t = [z_t, g_t]'$. The calibration of the divisible labor economy is retained, except for $\zeta = 60$, $f = 324.8$, and $\eta = 3.89$ (Burnside and Eichenbaum 1996). Finally, the analysis can be based on $\tau$-order VAR processes with $\mathbf{x}_t = [z_t, g_t, n_{t+1}]'$ and $\tau \geq 2$. These lag lengths are needed because the modified decision rule includes two lags of employment.

## Data Appendix

This appendix describes the U.S. seasonally adjusted quarterly data covering the 1960:II to 1993:IV period. The Citibase data mnemonics are presented on the right-hand side of the following definitions:

$Pop$ $= P16$ is the civilian noninstitutional population aged 16 or older, which is expressed in thousands of persons for the last month of each quarter;

$P$ $= (GCN + GCS)/(GCNQ + GCSQ)$ is the implicit 1987 deflator for consumption in nondurables and services;

$C$ $= [(GCN + GCS) \times 1000000]/(Pop \times P)$ is per capita consumption of nondurables and services;

$G$ $= [(GGNN + GGOSA + GGSN + GGSA) \times 1000000]/(Pop \times P)$ is per capita government expenditures on nondurables and services;

$I$ $= [(GIF + GCD + GGE - GGNN - GGOSA - GGSN - GGSA) \times 1000000]/(Pop \times P)$ is per capita gross private domestic fixed investment plus consumer durables plus government durables and structures;

$N$ $= (LHOURS \times 1000 \times 52)/(4 \times Pop)$ is per capita total hours worked, which is constructed from the quarterly average of the manhours employed per week reported in the household survey;

$Y$ $= C + G + I$ is per capita output;

$M$ $= P \times C$ is per capita money stock;

$K$ $= I_{-1} + (1 - \delta)K_{-1}$ is per capita capital stock, where $\delta = 0.021$, $K_0 = k_0 Z_{-1}$, and $k_0$ is set to its steady state value;

$W$ is labor effort, which is constructed from the first order condition $\frac{\eta N_t f}{T - \zeta - W_t f} = (1 - \alpha)\frac{Y_t}{C_t W_t}$ with $\eta = 3.89$, $\alpha = 0.344$, $f = 324.8$, $T = 1369$, and $\zeta = 60$;

$Z$ is technology, which is constructed from the aggregate production function — that is, (i) $Y_t = K_t^{\alpha}(Z_t N_t)^{1-\alpha}$ with $\alpha = 0.344$ for divisible labor, indivisible labor, and nominal wage contracts; (ii) $Y_t = (K_t)^{\alpha}(N_t Z_t)^{1-\alpha}\exp\left[-\frac{\xi}{2}\left(\frac{\Delta N_t}{N_{t-1}}\right)^2\right]$ with $\alpha = 0.344$ and $\xi = 0.36$ for labor adjustment costs; and (iii) $Y_t = K_t^{\alpha}(Z_t N_t W_t f)^{1-\alpha}$ with $\alpha = 0.344$ and $f = 324.8$ for labor hoarding.

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**Table 1. The Volatility of Employment: Basic Results**

| Volatility | Observed | | Predicted | Ratio |
|---|---|---|---|---|
| | SE | Process | | |
| $\sigma_n$ | 3.529 | 3.681 | 1.505 | 0.409<br>(0.000) |
| $\sigma_{\Delta n}$ | 0.856 | 0.838 | 0.454 | 0.542<br>(0.000) |
| $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$ | 0.977 | 0.904 | 0.430 | 0.475<br>(0.000) |

Note: $\sigma_x$ denotes the standard deviation of $x_t$ in percentages, where $x_t{=}n_t$, $\Delta n_t$, and $\Delta \ln(Y_t)$. $n_t$ and $\Delta \ln(Y_t)$ are the logarithm of per capita hours and the growth rate of per capita output. The observed standard deviations are obtained from sample estimates [SE] and from (4) [Process]. The predicted standard deviations are obtained from (5). Entries under Ratio are the relative values of predicted to observed standard deviations. Numbers in parentheses are the $p$-values associated with the $\chi^2(1)$ statistic of the test that this ratio is unity. This statistic uses the variance of the ratio, which is computed as $D'\Upsilon D$ — where $D$ is the vector of numerical derivatives of the ratio with respect to the estimated parameters in (4) and $\Upsilon$ is the covariance matrix of these parameters. For $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$, $\Upsilon$ accounts for the covariance between the estimated parameters from the process involving employment and those from the process involving adjusted output. Calculations pertaining to predicted volatility use the calibration discussed in Section 2.

**Table 2. Granger-Causality Tests**

| $\tau$ | $n \rightarrow z$ | $n \rightarrow g$ | $\chi^2(2\tau)$ |
|---|---|---|---|
| 1 | -0.073 | 0.129 | 7.159 |
| | (0.017) | (0.074) | (0.028) |
| 2 | -0.090 | 0.176 | 15.654 |
| | (0.005) | (0.019) | (0.003) |
| 4 | -0.090 | 0.139 | 13.155 |
| | (0.009) | (0.097) | (0.107) |
| 8 | -0.101 | 0.194 | 34.090 |
| | (0.007) | (0.058) | (0.005) |

Note: $\tau$ denotes the lag length of the unrestricted VAR process (6). Entries under $n \rightarrow z$ and $n \rightarrow g$ are the estimates ($p$-values) of the sum of lagged employment coefficients in the technology growth equation and in the adjusted government expenditures equation. Entries under column $\chi^2(2\tau)$ are the $\chi^2$ statistics ($p$-values) of the test that all lagged employment coefficients in the technology growth and adjusted government expenditures equations are jointly null.

**Table 3. The Volatility of Employment: Superior Information**

| | $\sigma_n$ | | | $\sigma_{\Delta n}$ | | | $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| $\tau$ | O | P | Ratio | O | P | Ratio | O | P | Ratio |
| 1 | 3.726 | 1.975 | 0.530 | 0.839 | 0.784 | 0.935 | 0.978 | 0.689 | 0.704 |
| | | | (0.014) | | | (0.753) | | | (0.062) |
| 2 | 3.639 | 2.330 | 0.640 | 0.834 | 0.879 | 1.054 | 0.973 | 0.755 | 0.775 |
| | | | (0.123) | | | (0.798) | | | (0.162) |
| 4 | 3.688 | 2.934 | 0.798 | 0.835 | 0.888 | 1.063 | 0.980 | 0.787 | 0.803 |
| | | | (0.490) | | | (0.771) | | | (0.255) |
| 8 | 3.740 | 2.932 | 0.784 | 0.870 | 1.236 | 1.421 | 1.018 | 0.952 | 0.936 |
| | | | (0.512) | | | (0.488) | | | (0.844) |

Note: $\tau$ is the lag length of the unrestricted VAR process (6). $\sigma_x$ denotes the standard deviation of $x_t$ in percentages, where $x_t = n_t$, $\Delta n_t$, and $\Delta \ln(Y_t)$. $n_t$ and $\Delta \ln(Y_t)$ are the logarithm of per capita hours and the growth rate of per capita output. Entries under O and P are the observed and predicted standard deviations. Entries under Ratio are the relative values of predicted to observed standard deviations. Numbers in parentheses are the $p$-values associated with the $\chi^2(1)$ statistic of the test that this ratio is unity. This statistic uses the variance of the ratio, which is computed as $D'\Upsilon D$ — where $D$ is the vector of numerical derivatives of the ratio with respect to the unrestricted VAR parameters and $\Upsilon$ is the covariance matrix of these parameters. For $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$, $\Upsilon$ accounts for the covariance between the parameters from the unrestricted VAR process involving employment and those from the unrestricted VAR process involving adjusted output. Calculations pertaining to predicted volatility use the calibration discussed in Section 2.

**Table 4. The Volatility of Employment: Extensions**

| | $\sigma_n$ | $\sigma_{\Delta n}$ | $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$ |
|---|---|---|---|
| | Ratio | Ratio | Ratio |
| Divisble Labor | 0.640 | 1.054 | 0.775 |
| | (0.123) | (0.798) | (0.162) |
| Nominal Wage Contracts | 2.272 | 3.506 | 1.940 |
| | (0.071) | (0.000) | (0.000) |
| Labor Adjustment Costs | 1.710 | 0.843 | 0.653 |
| | (0.820) | (0.331) | (0.001) |
| Indivisble Labor | 0.976 | 1.996 | 1.194 |
| | (0.939) | (0.062) | (0.521) |
| Labor Hoarding | 0.719 | 0.989 | 1.025 |
| | (0.219) | (0.973) | (0.947) |

Note: The lag length of the unrestricted VAR process is $\tau=2$. $\sigma_x$ denotes the standard deviation of $x_t$ in percentages, where $x_t=n_t$, $\Delta n_t$, and $\Delta \ln(Y_t)$. $n_t$ and $\Delta \ln(Y_t)$ are the logarithm of per capita hours and the growth rate of per capita output. Entries are the relative values of predicted to observed standard deviations. Numbers in parentheses are the $p$-values associated with the $\chi^2(1)$ statistic of the test that this ratio is unity. This statistic uses the variance of the ratio, which is computed as $D'\Upsilon D$ — where $D$ is the vector of numerical derivatives of the ratio with respect to the unrestricted VAR parameters and $\Upsilon$ is the covariance matrix of these parameters. For $\sigma_{\Delta n}/\sigma_{\Delta \ln(Y)}$, $\Upsilon$ accounts for the covariance between the parameters from the unrestricted VAR process involving employment and those from the unrestricted VAR process involving adjusted output. Calculations pertaining to predicted volatility use the calibrations discussed in the Technical Appendix.

Figure 1a. Responses of Employment: Basic Results

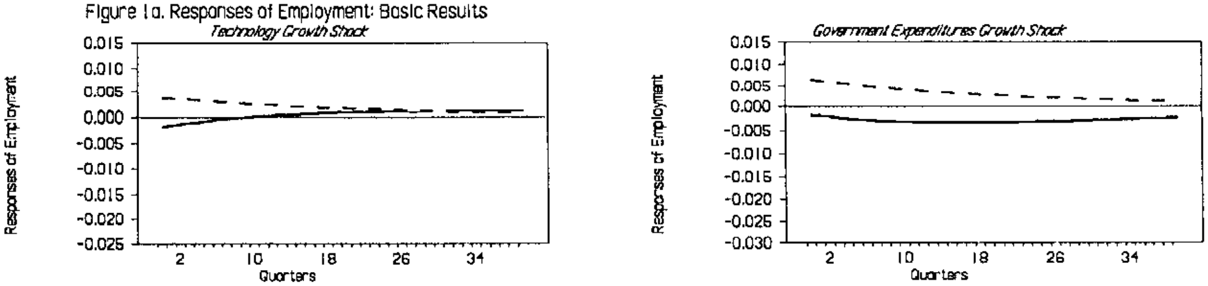
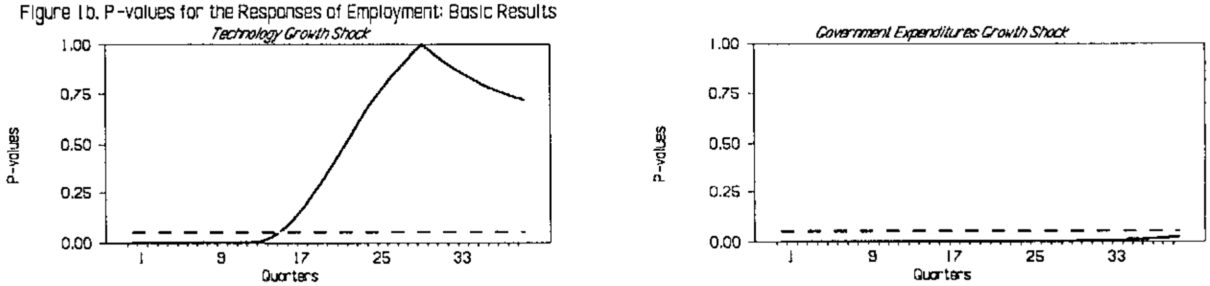



Figure 1b. P-values for the Responses of Employment: Basic Results




Note: In Panel A, the solid and dashed lines correspond to observed and predicted responses of employment respectively. In Panel B, the solid and dashed lines are the $p$-values and the 5 percent level of significance. The $p$-values are associated with a $\chi^2(1)$ statistic testing that the difference between observed and predicted responses for each quarter is null. This statistic uses the variance of the difference, which is computed as $D'\Upsilon D$ — where $D$ is the vector of numerical derivatives of the difference with respect to the estimated parameters in (4) and $\Upsilon$ is the covariance matrix of these parameters. Calculations pertaining to predicted responses use the calibration discussed in Section 2.

Figure 2a. Responses of Employment: Superior Information

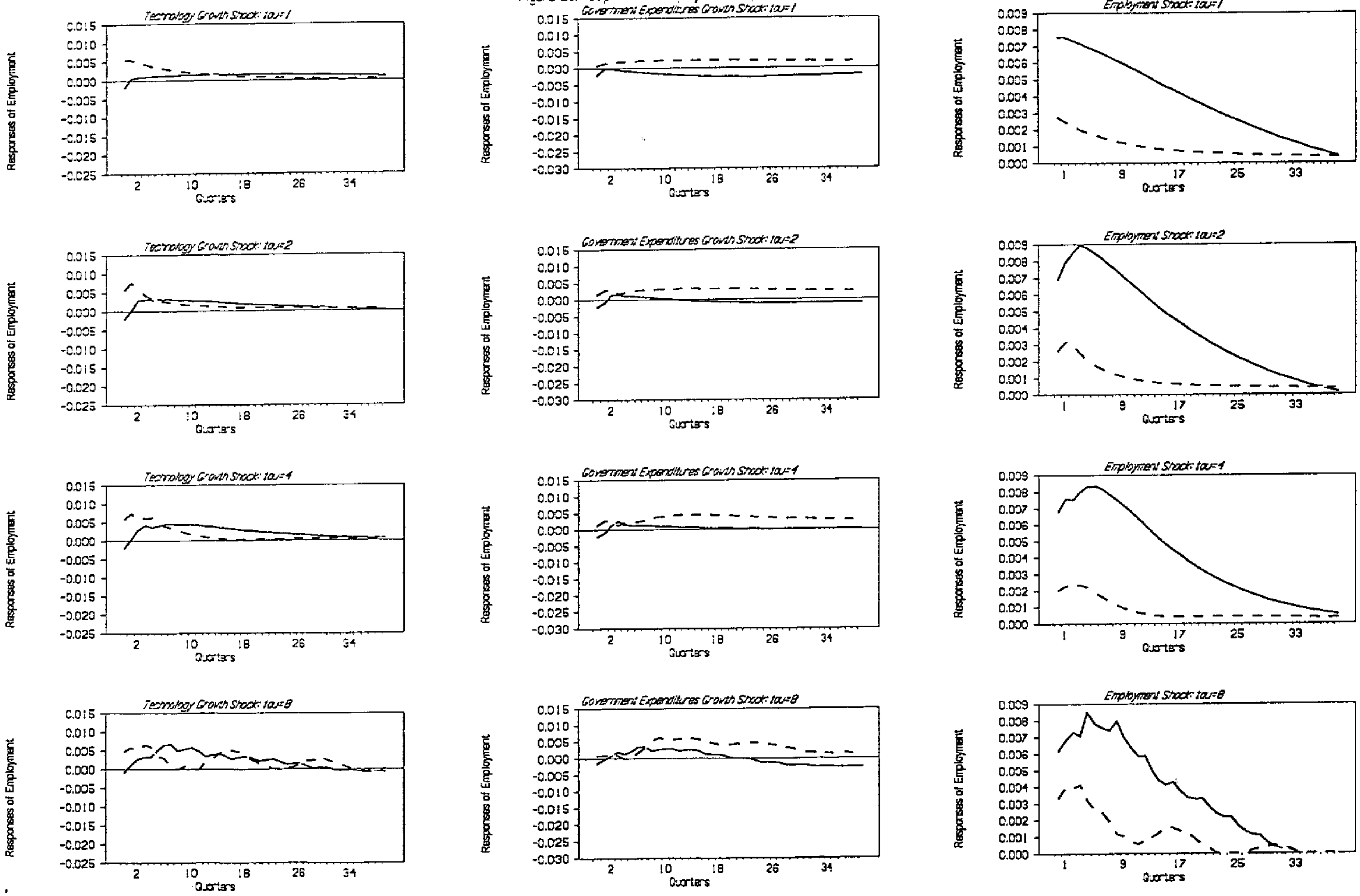
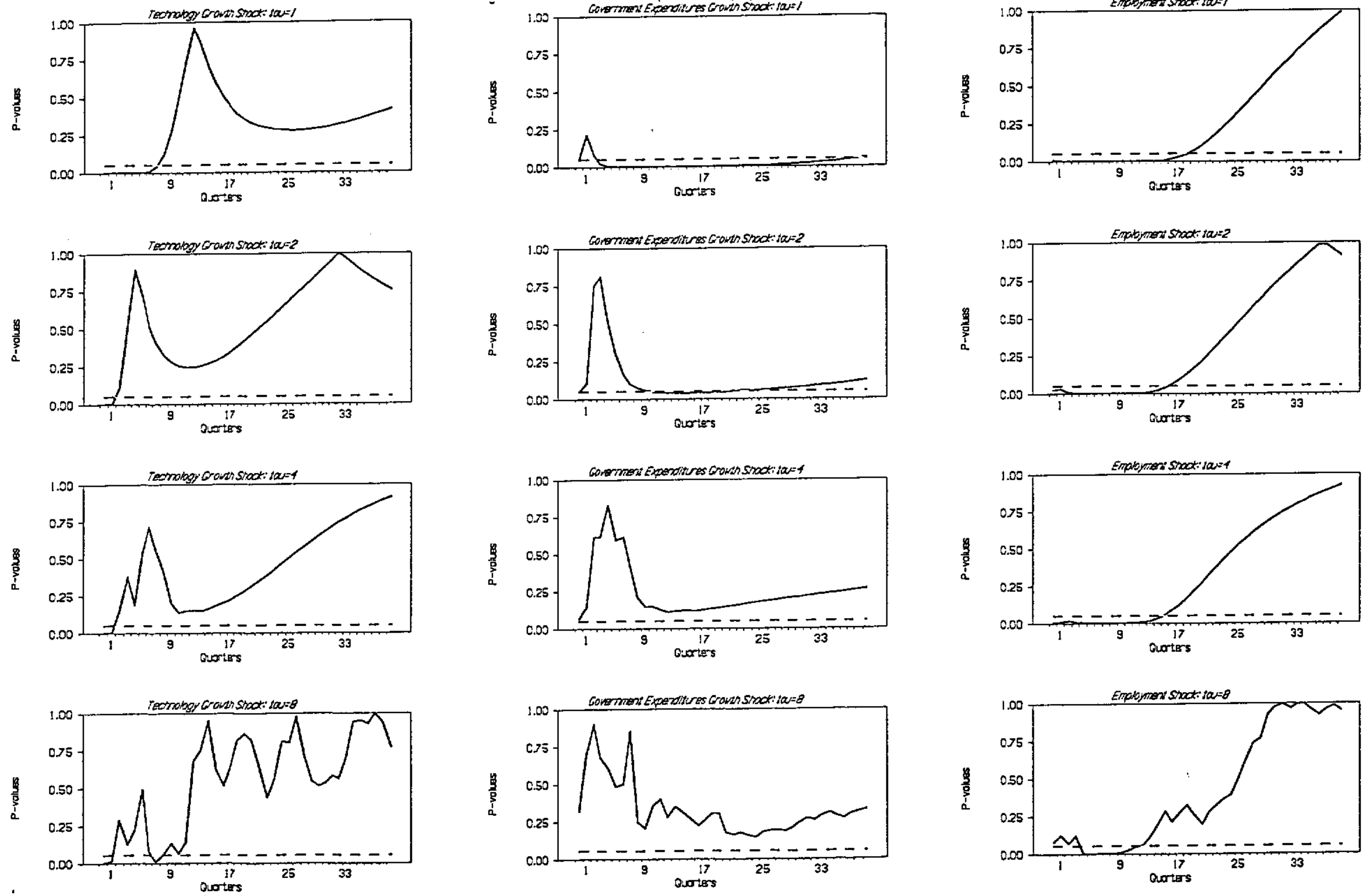


Figure 2b. P-values for the Responses of Employment: Superior Information




Note: In Panel A, the solid and dashed lines correspond to observed and predicted responses of employment respectively. In Panel B, the solid and dashed lines are the $p$-values and the 5 percent level of significance. The $p$-values are associated with a $\chi^2(1)$ statistic testing that the difference between observed and predicted responses for each quarter is null. This statistic uses the variance of the difference, which is computed as $D'\Upsilon D$—where $D$ is the vector of numerical derivatives of the difference with respect to the unrestricted $\tau$-order VAR parameters and $\Upsilon$ is the covariance matrix of these parameters. Calculations pertaining to predicted responses use the calibration discussed in Section 2.

Figure 3a. Responses of Employment: Nominal Wage Contracts

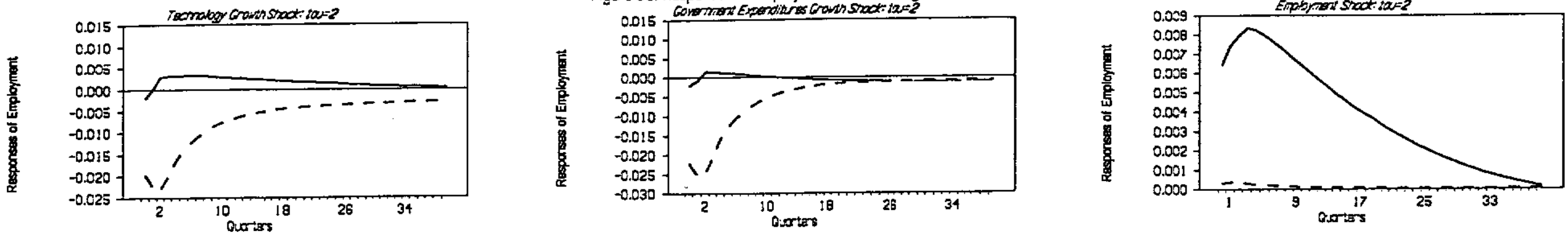



Figure 3b. P-values for the Responses of Employment: Nominal Wage Contracts

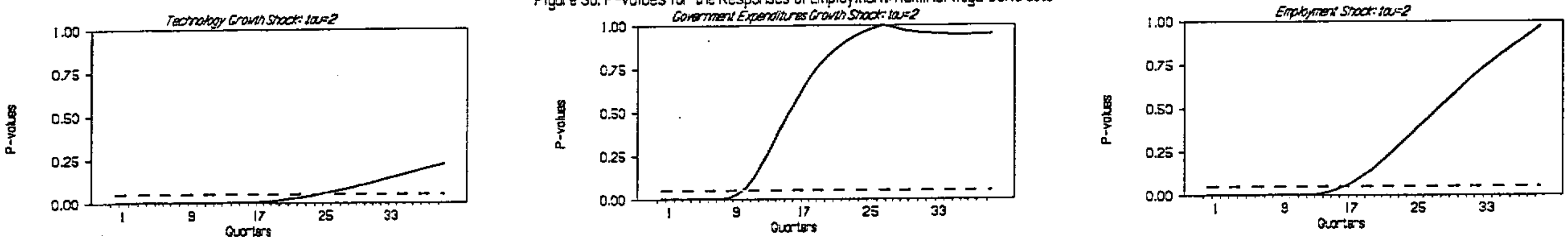



Figure 4a. Responses of Employment: Labor Adjustment Costs

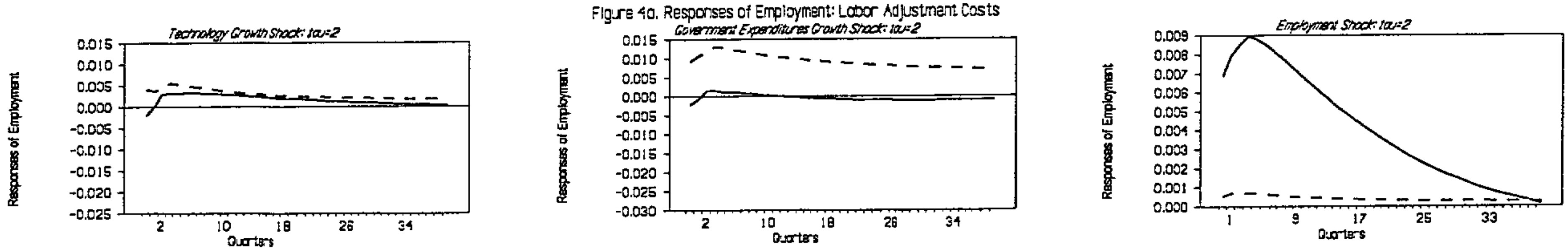



Figure 4b. P-values for the Responses of Employment: Labor Adjustment Costs

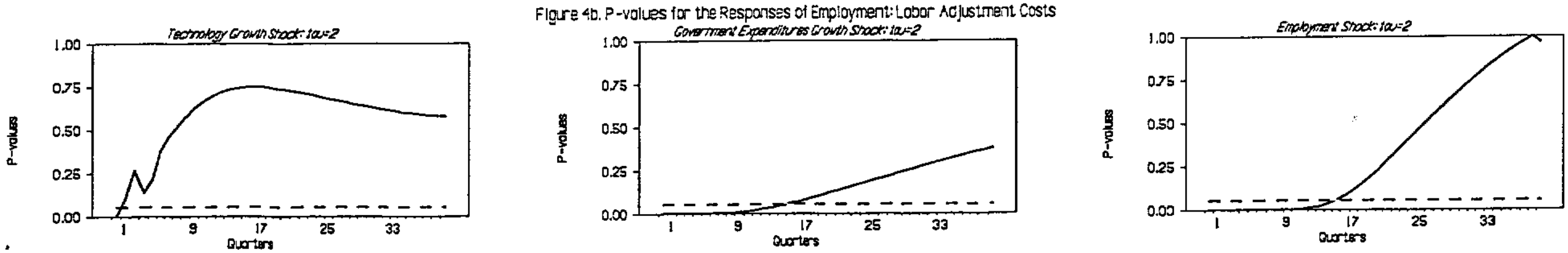


Figure 5a. Responses of Employment: Indivisible Labor

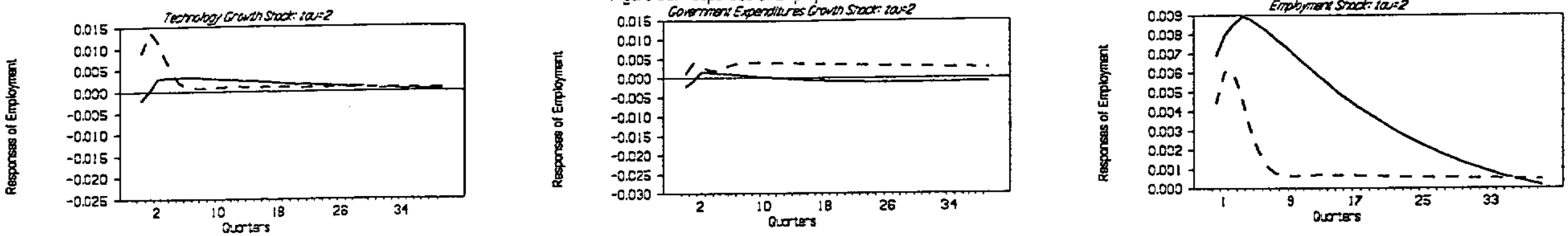



Figure 5b. P-values for the Responses of Employment: Indivisible Labor

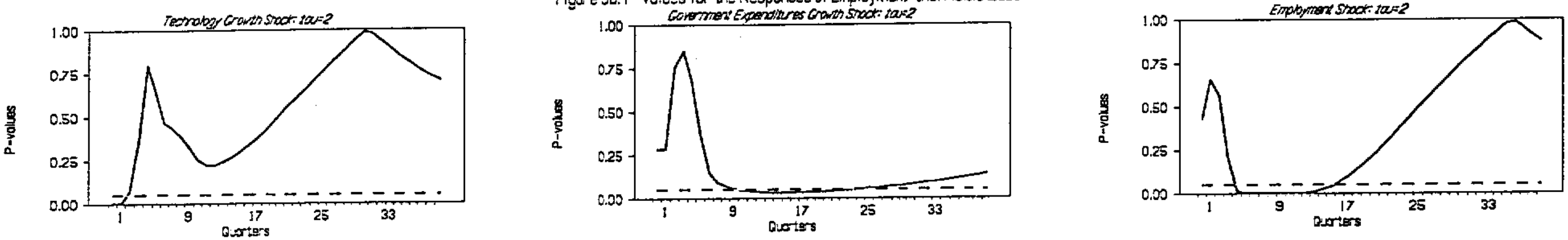



Figure 6a. Responses of Employment: Labor Hoarding

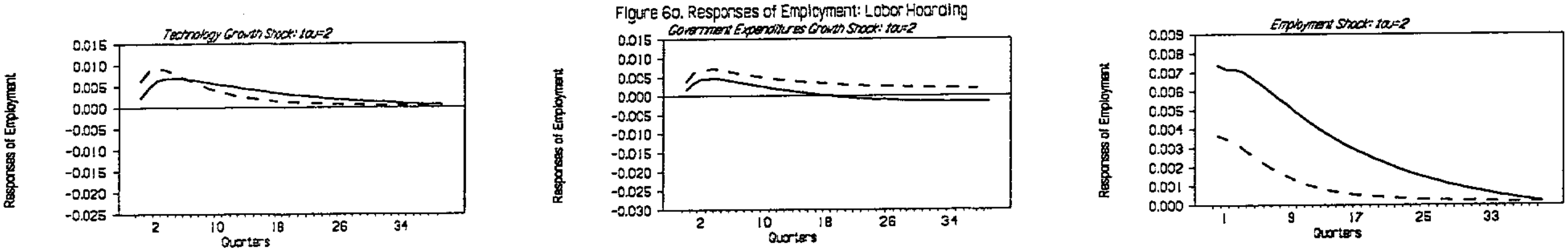
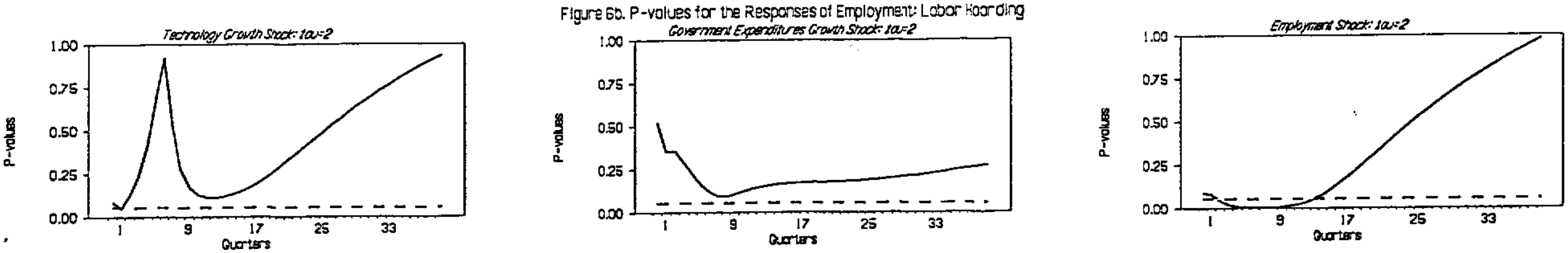



Figure 6b. P-values for the Responses of Employment: Labor Hoarding




Note: In Panel A, the solid and dashed lines correspond to observed and predicted responses of employment respectively. In Panel B, the solid and dashed lines are the $p$-values and the 5 percent level of significance. The $p$-values are associated with a $\chi^2(1)$ statistic testing that the difference between observed and predicted responses for each quarter is null. This statistic uses the variance of the difference, which is computed as $D'\Upsilon D$—where $D$ is the vector of numerical derivatives of the difference with respect to the unrestricted second-order VAR parameters and $\Upsilon$ is the covariance matrix of these parameters. Calculations pertaining to predicted responses use the calibration discussed in the Technical Appendix.