Rochester Center for
Economic Research

The Business Cycle with Nominal Contracts

Cho, Jang-Ok and Thomas F. Cooley

Working Paper No. 260
January 1991

University of
Rochester

The Business Cycle with Nominal Contracts

Jang-Ok Cho and Thomas F. Cooley

Rochester Center for Economic Research
Working Paper No. 260

January 1991

The Business Cycle with Nominal Contracts

Jang–Ok Cho
Queens University

Thomas F. Cooley
University of Rochester

Rochester Center for Economic Research
Working Paper No. 260

December 17, 1990

First Draft, November 1990

Preliminary.

We have received helpful comments from David Chapman, Gary Hansen, Michael Keane, Lee Ohanian, Edward Prescott, and Warren Weber. The usual disclaimer applies. This research is supported in part by NSF Grant SES-8921346 and the Olin Foundation.

Abstract

In this paper we study and compare the implications of both nominal price contracts and nominal wage contracts for the transmission of shocks in an equilibrium business cycle model. The model economy is based on the neoclassical growth model supplemented by the assumption that cash is needed to purchase goods. We consider two variations of the standard recursive competitive equilibrium concept that are motivated by the work of Gray (1976), and Fischer (1977). In the first variation, households and firms specify in advance the nominal wage. In this arrangement households cede to firms the right to determine aggregate hours and firms maximize profits. The second variation assumes that the firm specifies in advance the price at which goods will be exchanged and agrees to produce all that will be demanded at that price.

We use the equilibrium constructs just described to address three issues. First, we consider whether monetary shocks, propagated by nominal contracts, constitute a viable alternative to technology shocks as a source of aggregate fluctuations. Our results suggest that, while monetary shocks and nominal rigidities succeed in causing output volatility of the required magnitude, the resulting data have properties that are inconsistent with several key features of U.S. data. Second, we ask whether there are important differences between wage rigidity and price rigidity. The differences are significant; the price contracting economy produces data with a correlation structure that is inconsistent with important features of U.S. data. Finally we ask whether nominal rigidities do help to match the features of the data and ask how much rigidity is necessary. Our results show that nominal rigidity might be an important missing element of equilibrium business cycle models and that a very small amount of rigidity helps to reconcile the data generated by the model with the U.S. data.

1. **Introduction.**

Kydland and Prescott (1982) changed the direction of macroeconomic thinking by showing that a simple neoclassical growth model, parametrized on the basis of existing microeconomic evidence and perturbed by shocks to technology, could replicate many of the features of the U.S. business cycle. In the aftermath of their important contribution, much business cycle research has been based on models where the driving forces of the real economy are technology shocks and where monetary factors play no role. This change in focus stands in sharp contrast to business cycle research of a decade ago in which monetary shocks, particularly unanticipated shocks played the predominant role in models of business cycles. It is now widely accepted that technology shocks by themselves cannot provide a complete description of the business cycle phenomena. Kydland (1989) and Cooley & Hansen (1989) have explored the quantitative features of Kydland-Prescott type models that include monetary shocks, but neither found much effect of such shocks at the business cycle frequencies.[1] Perhaps these negative findings were inevitable and foreseeable since neither model incorporates the feature that is viewed in much of the macroeconomic literature as the primary transmission mechanism for monetary shocks -- price rigidities. In this paper we explore the quantitative implications of such rigidities in an equilibrium business cycle model with money.

The role of nominal contracts in the propagation of nominal shocks has been explored in many theoretical models and to a lesser extent empirically. Initially, these kinds of price rigidities were thought to be most important in the labor market. This focus resulted from the prevalence of nominal contracts in observed labor markets: a relatively large portion of the labor force consists of salaried workers and a significant portion of the manufacturing labor force participate in long term contracts. The importance of wage contracts is also often inferred from the observation that aggregate hours fluctuate more than wages. More recently, attention has shifted to the importance of rigid goods prices. Mankiw (1985), Parkin (1986), Akerlof & Yellen (1985) and others have stressed the importance of price rigidities that arise as a consequence of the costs of changing prices. Again, the importance of this phenomenon is frequently inferred from the observation that, in the aggregate, quantities seem to fluctuate more than prices.[2] In a recent

[1] Kydland's model is designed to capture the effect of unanticipated monetary shocks while in Cooley and Hansen it is anticipated monetary shocks, operating through a cash-in-advance constraint, that matter.

[2] Advocates of this view also cite the work of Dennis Carlton (1986) who studies the behavior of prices at the firm and industry level. Rotemberg (1986) and Gordon (1990) review this evidence.

paper Lucas (1990) has argued that price and wage rigidities are essentially equivalent in their implications for the propagation of monetary shocks. All of this literature has in common that it views the importance of nominal rigidities in terms of their potential for propagating monetary shocks.

In this paper we study and compare the implications of both nominal price contracts and nominal wage contracts for the transmission of shocks in an equilibrium business cycle model.[3] We introduce multi-period contracts into an economy that is subject to both technology shocks and monetary shocks. The model economy is a direct descendent of those considered by Kydland and Prescott(1982), Hansen (1985) and Cooley and Hansen (1989). This economy is based on the neoclassical growth model supplemented by the assumption that cash is needed to purchase goods. We consider two variations of the standard recursive competitive equilibrium concept that are motivated by the work of Gray (1976), and Fischer (1977). In the first variation, households and firms specify in advance the nominal wage. In this arrangement households cede to firms the right to determine aggregate hours and firms maximize profits. The second variation assumes that the firm specifies in advance the price at which goods will be exchanged and agrees to produce all that will be demanded at that price. We beg the important question of why firms and workers enter into these contracts. Our view is that, if they turn out to be quantitatively important in understanding the business cycle, the next step will be to explore the quantitative implications of models where these contracts emerge endogenously.

Having agreed to the arrangements just described, households and firms behave as typical neoclassical agents: they solve for the equilibrium and form their expectations using the equilibrium decision rules of the economy. Households and firms optimize and all markets clear. When the equilibrium concept involves nominal wage contracting, output and employment depend on innovations to prices and innovations to technology. When the equilibrium involves price contracting, output and employment depend on innovations to technology and to demand. We study the quantitative implications of these equilibria by calibrating and simulating the economies and exploring the properties of the data.

We use the equilibrium constructs just described to address three issues. First, we consider whether monetary shocks, propagated by nominal contracts, constitute a viable

[3] The role of one period wage and price contracts in a similar setting is explored in recent paper by Cho (1990). King (1990) examines several of the issues considered here in the context of a neoclassical model that incorporates only monetary shocks and but without an explicit model of money holding.

alternative to technology shocks as a source of aggregate fluctuations. Our results suggest that, while monetary shocks and nominal rigidities succeed in causing output volatility of the required magnitude, the resulting data have properties that are inconsistent with several key features of U.S. data. Second, we ask whether there are important differences between wage rigidity and price rigidity. The differences are significant; the price contracting economy produces data with a correlation structure that is inconsistent with important features of U.S. data. Finally we ask whether nominal rigidities do help to match the features of the data and ask how much rigidity is necessary. Our results show that nominal rigidity might be an important missing element of equilibrium business cycle models and that a very small amount of rigidity helps to reconcile the data generated by the model with the U.S. data.

The paper proceeds as follows. In the next section we describe the basic features of the model economy to be studied. In Section 3 we describe the nature of the nominal wage contracts and the equilibrium concept that we use with those contracts. This is followed in Section 4 with a description of the nominal price contracts and the associated equilibrium concept used. Section 5 describes how the model is calibrated and solved. In Section 6 we present the quantitative results of simulating these artificial economies and describe the important features of the data. The final section concludes and offers some comments on unresolved issues.

2. The Economy

The economy consists of a continuum of identical infinitely lived agents (or households). Agents consume and invest the output produced by a single firm with access to a constant returns to scale technology. Each agent is endowed with one unit of time per period, initial capital stock $k_0=k$, and initial nominal money holdings m_0. We use the convention throughout that lowercase letters denote individual variables and capital letters denote the aggregate per-capita counterparts. We first describe the problem faced by consumers.

Each agent maximizes his expected lifetime utility which is assumed to be time separable.

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \cdot u(c_t, \ell_t, e_t), \tag{2.1}$$

where c_t is consumption, ℓ_t is leisure in a week, e_t is the weeks worked in a period, and β is a discount factor. We assume the utility function is separable in consumption, leisure and a "fixed" cost function $\psi(e)$:

$$u(c_t, \ell_t, e_t) = u(c_t) - v(1-\ell_t)e_t - \psi(e_t) \tag{2.2}$$

The term $\psi(e)$ captures the fixed cost of working additional weeks and $\psi'(e) > 0$. This specification of preferences is from Cho and Cooley (1989) and is justified in some detail there. It differs from some commonly used specifications in that it displays fluctuations in both average hours of work (the intensive margin) and employment (the extensive margin). One way to think of the consumer's behavior is as follows. Each period, say a quarter, is divided into weeks and each individual faces two choices: he must choose the fraction of weeks in each period to work and he must choose the number of hours to work per week. Since all agents are identical, the aggregate per-capita E_t can be interpreted as the employment rate of the economy. [4] The specific functional form of (2.2) is:

---

[4] Most equilibrium business cycle models one of two conventions. Either all fluctuations take place on the intensive margin (Kydland and Prescott) or all fluctuations occur on the extensive margin (Hansen). It is well known that the former generate a volatility of hours that is too low compared to U.S. data, while the latter generates fluctuations in hours that are too volatile compared to the data. The specification in equation (2.2) is designed to be consistent with the observation that in the U.S. data we observe substantial variation in both margins, but it will generate less volatility of aggregate hours than the indivisible labor model. Because our objective is to assess the contribution of nominal contracts, which we expect on *a priori* grounds to generate more volatility in output and hours, we would like to do this against a background that more closely resembles the features of the labor market.

(2.2′) $$u(c_t,\ell_t,e_t) = \ln(c_t) - \frac{\alpha_1}{1+\gamma} \cdot n_t^{1+\gamma} \cdot e_t - \frac{\alpha_2}{1+\tau} \cdot e_t^{1+\tau}$$

where $n_t=1-\ell_t$. This specification satisfies the usual regularity and Inada conditions.

Agents in this economy hold money because it is required to purchase the consumption good. They face a cash-in-advance constraint of the form

(2.3) $$P_t c_t \le m_{t-1} + (g_t - 1) M_{t-1},$$

where m_{t-1} represents money carried over from previous period, $(g_t-1)M_{t-1}$ is the lump sum money transfer, and P_t is the price level in period t. The growth rate of money is known at the beginning of each period.

The budget constraint facing the representative household can be written as

(2.4) $$P_t(c_t+x_t)+m_t = W_t n_t e_t + r_t k_t + m_{t-1} + (g_t-1)M_{t-1},$$

where x_t is investment, W_t and r_t are the nominal wage rate and the nominal rental rate of capital respectively and $n_t e_t$ is the total hours of work of this agent.

Money is injected into the economy through lump sum transfers. If we let g_t denote the growth rate of money in period t, money follows the process:

(2.5) $$M_{t+1} = g_{t+1} M_t.$$

The growth rate g_t is determined by process

(2.6) $$\ln(g_{t+1}) = \eta \cdot \ln(g_t) + \omega_{t+1},$$

where ω_t is an iid random variable,

(2.7) $$\omega_t \sim N[(1-\eta)\ln(\bar{g}),\ \sigma_\eta^2],$$

and $\bar{g}$ is the unconditional mean of the money growth rate.

The firm in this economy produces output, Y_t, according to a constant returns to scale production function that is subject to an aggregate productivity shock.

(2.8) $$Y_t = \lambda_t K_t^{\theta} Q_t^{1-\theta},$$

where λ_t is the productivity shock, $Q_t = N_t E_t$ is aggregate hours of work, and K_t is the aggregate capital stock. We assume (2.8) is twice continuously differentiable and concave. If we let $z_t = \ln(\lambda_t)$, then z_t is assumed to follow the AR(1) process:

(2.9) $$z_{t+1} = \rho z_t + \epsilon_{t+1}, \quad 0 \leq \rho \leq 1,$$

where ϵ_t is an i.i.d. random variable with mean 0 and variance σ_{ϵ}^2. It is assumed that the technology shock is known at the beginning of each period before decisions are made.

Following Kydland and Prescott (1982), we assume that time is required to build new productive capital. Let S_{it} be the number of projects i periods from completion for i = 1, 2, ..., I, where I denotes the required periods to build new productive capital. The same recursive representation as in Kydland and Prescott is used for the laws of motion of the aggregate capital stock.[5]

(2.10) $$K_{t+1} = (1-\delta)K_t + S_{1t}$$

(2.11) $$S_{i,t+1} = S_{i+1,t}, \quad i = 1, 2, \ldots, I-1,$$

where δ is the capital depreciation rate. Note that there are I types of capital. Let φ_i, i = 1, 2, ..., I, denote the fraction of the resources allocated to the investment project in the i-th stage from the last. Total investment in period t is,

(2.12) $$X_t = \sum_{i=1}^{I} \varphi_i S_{it}$$

and the real price of productive capital in a steady state can be obtained as,

$$p_k = \sum_{i=1}^{I} \varphi_i / \beta^{i-1}.$$

[5] There are a corresponding pair of equations for the individual level capital stocks.

The time-to-build technology may appear to be an inessential complication in this model but it actually serves an important purpose. With this assumption, appropriately specified, the capital stock can be represented as known at the time contracts are entered into.[6]

Before proceeding we introduce a change in variables to make the problem stationary and facilitate solving for an equilibrium. Let $\hat{m}_t = m_t/M_t$ and $\hat{P}_t = P_t/M_t$. Then the cash-in-advance constraint can be rewritten as,

(2.13) $$c_t \leq [\hat{m}_{t-1} + (g_t - 1)]/\hat{P}_t g_t \,.$$

We rewrite the budget constraint as,

(2.14) $$c_t + x_t + \hat{m}_t/\hat{P}_t = (\hat{W}_t/\hat{P}_t)n_t e_t + (\hat{r}_t/\hat{P}_t)k_t + (\hat{m}_{t-1} + g_t - 1)/(\hat{P}_t g_t),$$

where $\hat{W}_t = W_t/M_t$ and $\hat{r}_t = r_t/M_t$. Aggregating (2.14) and using the binding cash in advance constraint, we have:

(2.15) $$X_t + 1/\hat{P}_t \leq \lambda_t K_t^{\theta} Q_t^{1-\theta}$$

Equation (2.15) as an equilibrium condition in the output market that will play an important role below.

3. **Equilibrium With Nominal Wage Contracts.**

In this section we describe the arrangements that will constitute the equilibrium with nominal wage contracts. We will consider contracts in which the nominal wage rate for period t is determined in a contract before the period arrives. At the beginning of each period the technology and/or monetary shocks are revealed. Agents then choose their consumption, investment, working hours, weeks etc.. At the end of each period the future nominal wage rate is agreed to. We assume this process repeats over time. Under these assumptions the nominal wage contract can be described as follows:

---

[6] Alternatively, the whole history of shocks to technology would enter as state variables.

$$(3.1) \qquad \ln(W_t^c) = E[\ln(W_t) \mid \Omega_{t-j}]$$

where W_t^c is the nominal contract wage, W_t is the equilibrium processes of the nominal wage rate implied by the model, and Ω_{t-j} is the information set available in period t-j when the contract is set. It is assumed that $j \leq I$ so that the time-to-build is greater than the contracting period. This insures that $K_t \in \Omega_{t-j}$.

Nominal wage contracts like (3.1) have been emphasized by many authors (for example, see Fischer (1977), Gray (1976), and Taylor (1979, 1980)). Under these arrangements, workers are assumed to cede the firm the right to determine the aggregate hours in period t. The labor market equilibrium condition requires that the contract wage rate should be the expected value of the marginal product of labor:

$$(3.3) \qquad \ln(W_t^c) = E[z_t + \theta \cdot \ln(K_t) - \theta \ln(Q_t) + \ln(P_t) + \ln(1-\theta) \mid \Omega_{t-j}].$$

To obtain the contract nominal wage rate we require the processes governing $\ln(Q_t)$, and $\ln(P_t)$ in (3.3). We follow Fischer (1977), in that we use the equilibrium processes for P and Q from the model without nominal contracts.[7] Letting "~" denote these processes, we write the wage contract as:

$$(3.4) \qquad \ln(W_t^c) = \theta \ln(K_t) + \ln(1-\theta) + E[z_t - \theta \ln(\tilde{Q}_t) + \ln(\tilde{P}_t) \mid \Omega_{t-j}]$$

where we used the fact that $K_t \in \Omega_{t-j}$.

As in Fischer (1977), we can also consider staggering of the contracts. When we do the contract wage is written as,

$$(3.5) \qquad \ln(W_t^c) = \theta \ln(K_t) + \ln(1-\theta) + \sum_{k=0}^{j} f_k \cdot E[z_t - \theta \ln(\tilde{Q}_t) + \ln(\tilde{P}_t) | \Omega_{t-k}],$$

[7]Cho (1990) considers contracts where these equilibrium processes are determined in the contract model. Those contracts are more efficient than the Fischer contracts. We use the Fischer contracts because they are easier to simulate and quantitatively there is little difference from the Cho type contracts.

where $\sum_{k=0}^{j} f_k = 1$. If $f_0=1$, there are no nominal rigidities and wages are determined by spot transactions. If $f_0 < 1$, there are some nominal rigidities. One further assumption is that the contracts are indexed. Although there are many ways to index contracts, we assume that these are indexed by the series of investment projects initiated between the contracting period and the period when the contract wage and price are actually applied.[8]

The firm's problem is to maximize profits given the nominal wage contract. The first order conditions are:

$$(3.6) \qquad (1-\theta)P_t\lambda_t K_t^{\theta} Q_t^{-\theta} = W_t^c$$

$$(3.7) \qquad \theta P_t \lambda_t K_t^{\theta-1} Q_t^{1-\theta} = r_t.$$

Logging (3.6) and using the definition of Fischer contracts leads to an expression for employment in this equilibrium:

$$(3.8) \qquad \ln(Q_t) = E[\ln(\tilde{Q}_t) \mid \Omega_{t-j}] + (1/\theta) \cdot \{\ln(P_t) - E[\ln(\tilde{P}_t) \mid \Omega_{t-j}]\} + (1/\theta) \cdot \{\ln(\lambda_t) - E[\ln(\lambda_t) \mid \Omega_{t-j}]\}.$$

Equation (3.8) has a familiar form. Because the right to determine employment is ceded to firms, equation (3.8) determines the quantity of labor demanded by firms. The first term on the right hand side is the expected output as of the contract period t-j. The second term is the contribution of price "surprises" to output, while the third term is the contribution of productivity surprises to output. Thus, (3.8) embodies the familiar implication of many rational expectations models that unexpected shocks matter.[9]

We denote the quantity of labor determined by the firm as Q_t^F. Once the quantity of

---

[8]We choose the indexation scheme in the text because it helps us avoid the complicated problem of forming expectations on the path of investment projects initiated between the contracting date and the realization date. In fact, nominal contracts are usually indexed on the price path as in Gray (1976).

[9] If the contract is endogenous as in Cho (1990), $\tilde{P}_t$ and $\tilde{Q}_t$ should be the same as P_t and Q_t and so the efficiency gain from endogenizing the contract can be measured as:

$$EFF = E[\ln(\tilde{Q}_t) - \ln(Q_t) + (1/\theta)\{\ln(P_t) - \ln(\tilde{P}_t)\} \mid \Omega_{t-j}]$$

aggregate labor input is determined by the firm, the representative agent's choice of hours per week and fraction of weeks worked in the market sector are restricted by that choice:

$e_t \cdot n_t = Q^F_t$.

We next identify the state variables associated with the equilibrium. Since the contract wage in period t is set at the end of the period t-j, the money supply process between the two periods matters. The state variables from the money supply process are $\ln(g_{t-j})$, the log of the growth rate of money in the contract period and $\{\omega_h\}^t_{h=t-j+1}$, the monetary innovation after the contract wage has been set. The state variables from the productivity shock process are $\log(\lambda_{t-j})$, the size of the technology shock in the contracting period and $\{\epsilon_h\}^t_{h=t-j+1}$ the innovation in it after the contract. Since the time-to-build is longer than the contract period, the capital stock in period t is known at the time the contract wage is set and is a state variable. Lastly, the projects initiated before and after the contracting period, $\{S_{I,h}\}^{t-1}_{h=t-I+1}$, are state variables. We denote the aggregate state as:

$$(3.9) \qquad S(t) = [\ln(\lambda_{t-j}), \{\epsilon_h\}^t_{h=t-j+1}, \ln(g_{t-j}), \{\omega_h\}^t_{h=t-j+1}), K_t, \{S_{I,h}\}^t_{h=t-I+1}]^T,$$

where superscript T denote the transpose. In addition, individual agents take their individual capital stock, the series of immature (s_{t-j}) stocks, and money holdings from the previous period as state variables. The state vector for a household is

$$(3.10) \qquad s(t) = [S(t), k_t, \{s_{I,h}\}^{t-1}_{h=t-I+1}, \hat{m}_{t-1}]^T.$$

In equilibrium $k_t=K_t$, $s_{I,h} = S_{I,h}$, $\forall$ h, and $\hat{m}_{t-1}=1$ should hold.

Equilibrium.

We represent the problem facing a household using a recursive structure. Define $V(s)$ to be the equilibrium maximized present value of the utility stream of the representative household as of period t and let primes denote next period values. Then, the Bellman equation associated with the household's problem can be written as follows :

$$(3.11) \qquad V(s) = \max\left[\ln(c) - \frac{\alpha_1}{1+\gamma}\cdot n^{1+\gamma}\cdot e - \frac{\alpha_2}{1+\tau}\cdot e^{1+\tau} + \beta\, E[V(s')) \mid s\,] \right]$$

s.t. $c + x + \hat{m}/\hat{P} = (\hat{W}^c/\hat{P})n\cdot e + (\hat{r}/\hat{P})k + (\hat{m} + g\text{-}1)/(\hat{P}g)$

$c = (\hat{m} + g\text{-}1)/(\hat{P}g)$

$\ln(\lambda') = \rho\ln(\lambda) + \epsilon'$

$\ln(g') = \eta\ln(g) + \omega'$

$k' = (1\text{-}\delta)k + s_1$

$K' = (1\text{-}\delta)K + S_1$

$s_i' = s_{i+1}$, $i = 1, 2, \cdots, I\text{-}1,$

$S_i' = S_{i+1}$, $i = 1, 2, \cdots, I\text{-}1,$

$$X = \sum_{i-1}^{I} \varphi_i S_i$$

$$x = \sum_{i-1}^{I} \varphi_i s_i$$

$e\cdot n = Q^F$

$c \geq 0,\ x \geq 0,\ \hat{m} \geq 0,\ 0 \leq n \leq 1,\ 0 \leq e \leq 1\,.$

Note here that the real contract wage rate and rental price of capital are the marginal product of those inputs.

Definition 1:

A stationary competitive equilibrium for this economy consists of a set of decision rules $c(s)$, $s_i(s)$, $\hat{m}(s)$, $n(s)$, and $e(s)$, a set of aggregate decision rules, $C(S)$, $S_I(S)$, $N(S)$, and $E(S)$, price functions, $\hat{P}(S)$ and $\hat{r}(S)$, and a value function $V(s)$ such that:

(i) the functions $V(s)$, $S_I(S)$, $N(S)$, $E(S)$, and $\hat{W}(S)$ satisfy (3.11) and $c(s)$, $s_I(s)$, $\hat{m}(s)$, $n(s)$, and $e(s)$ are the associated decision rules;

(ii) $s_I(s) = S_I(S)$, $n(s)=N(S)$, $e(s) = E(S)$, and $\hat{m}(s) = 1$ when $k=K$ and $\hat{m}=1$;

(iii) decision rules and pricing functions satisfy (3.10),

(iv) the functions $C(S)$ and $X(S)$ satisfy $C(S)+X(S) = Y(S)$, $\forall\, S$.

When we consider staggered contracts, equation (3.10) is modified as follows:

$$\text{(3.10')}\qquad \ln(Q_t) = \sum_{k=0}^{j} f_k \left[E[\ln(\tilde{Q}_t) | \Omega_{t-k}] + \frac{1}{\theta} \cdot \left[\ln(P_t) - E[\ln(\tilde{P}_t) | \Omega_{t-k}] \right] + \frac{1}{\theta} \cdot \left[\ln(\lambda_t) - E[\ln(\lambda_t) | \Omega_{t-k}] \right] \right]$$

The difference in the definition of equilibrium in this case is that we use (3.10') rather than (3.10) in (iii) of Definition 1.

4. Equilibrium with Nominal Price Contracts

In the equilibrium with nominal price contracts we assume that the goods price for period t is set in advance. At the beginning of each period the technology shock and money shock are revealed. Households choose their consumption, investment, working hours and weeks, and the firm produces the amount demanded at the prevailing price. At the end of each period the future nominal goods price is agreed to. The price contract is described as,

$$\text{(4.1)}\qquad \ln(P_t^c) = E[\ln(P_t) \mid \Omega_{t-j}]$$

where P_t^c is the contract price, P_t is the equilibrium price and Ω_{t-j} is the information available at the time. The importance of nominal price contracts, like (4.1), has been widely discussed by the "new" Keynesians (for example, see Blinder and Mankiw (1984), and Gordon (1990) for a survey). A theoretical version of nominal price contracting appears in Lucas (1990).

The condition for equilibrium in the goods market, (2.15), is used in calculating the contract price. We approximate equation (2.15) around the steady state to obtain the expression[10]

$$\text{(4.2)}\qquad \ln(\hat{P}_t^c) = E[\gamma_{10} + \gamma_{11}\ln(X_t) + \gamma_{12} z_t + \gamma_{13}\ln(K_t) + \gamma_{14}\ln(Q_t) \mid \Omega_{t-j}],$$

where $\gamma_{10} = \{X[1-\ln(X)] + [1+\ln(\hat{P})] - \lambda K^{\theta}Q^{1-\theta}[1-\ln(\lambda) - \theta\ln(K) - (1-\theta)\ln(Q)]\}\hat{P}$, $\gamma_{11} = X\hat{P}$, $\gamma_{12} = -\hat{P}\lambda K^{\theta}Q^{1-\theta}$, $\gamma_{13} = -\theta\hat{P}\lambda K^{\theta}Q^{1-\theta}$, $\gamma_{14} = -(1-\theta)\hat{P}\lambda K^{\theta}Q^{1-\theta}$, and the variables without subscript denote the steady state values of their subscripted counterparts. Here we know that $\gamma_{11} > 0$, $\gamma_{12} < 0$, $\gamma_{13} < 0$, and $\gamma_{14} < 0$. Again we follow Fischer and use the equilibrium

10 The steady state is the same as that for the model without contracts.

processes from the model without contracts (denoted by "~")to form expectations,

$$\text{(4.3)} \qquad \ln(\hat{P}^c_t) = \gamma_{10} + \gamma_{13}\ln(K_t) + E[\gamma_{11}\ln(\tilde{X}_t) + \gamma_{12} z_t + \gamma_{14}\ln(\tilde{Q}_t) \mid \Omega_{t-j}],$$

Because the firm commits itself to supply the quantity of output demanded at the pre-set contract price and because capital is predetermined, the real wage rate will not necessarily equal the marginal product of labor. For example, if the demand for output increases, the firm must increase its production and this means hiring more labor. This implies that the firm will pay higher nominal wages to attract more workers and/or increase the hours of those already working. Since labor may not be paid its marginal product, profit is not necessarily zero. Consequently, we must modify the budget constraint to include profit:

$$\text{(4.4)} \qquad c_t + x_t + \hat{m}_t/\hat{P}^c_t = (\hat{W}_t/\hat{P}^c_t)n_t e_t + (\hat{r}_t/\hat{P}^c_t)k_t + \Pi_t/P^c_t + (\hat{m}_{t-1}+g_t-1)/(\hat{P}^c_t g_t),$$

where P^c_t is the contract price and Π_t is the profit of the firm distributed as dividends.

Aggregating individual budget constraints and then linearizing the resulting goods market clearing condition around the steady state, we have:

$$\text{(4.5)} \qquad \ln(\hat{P}^c_t) = \gamma_{10} + \gamma_{11}\ln(X_t) + \gamma_{12}\ln(\lambda_t) + \gamma_{13}\ln(K_t) + \gamma_{14}\ln(Q_t),$$

where the γ_{ij}'s are defined in (4.2). We can rewrite (4.5) as:

$$\text{(4.6)} \qquad \ln(Q_t) = E[\ln(\tilde{Q}_t) \mid \Omega_{t-j}] + \gamma_{22}\{\ln(\lambda_t) - E[\ln(\lambda_t) \mid \Omega_{t-j}]\} + \gamma_{23}\{\ln(X_t) - E[\ln(\tilde{X}_t) \mid \Omega_{t-j}]\},$$

where $\gamma_{22}=-\gamma_{12}/\gamma_{14}<0$, $\gamma_{23}=-\gamma_{11}/\gamma_{14}>0$. Equation (4.6) is again reminiscent of many rational expectations models in which unexpected shocks matter, but the story is a bit different from the wage contract case. First, an unexpected increase in investment demand increases output and consequently labor input. This propagation channel has been emphasized in Keynesian macroeconomic models. Second, since γ_{22} is negative, an unexpected increase in the technology shock reduces the use of the labor input. In other words, an unexpected productivity increase affects labor demand adversely, a somewhat counter-intuitive implication. In addition, if the firm is to reduce the use of labor input given the contract price, it should lower the wage rate even though the productivity has increased. This also seems counter-intuitive. On the other hand, an unexpected increase in the supply of money increases aggregate demand without affecting aggregate supply initially, so a nominal shock has a positive effect on employment and output.

We have assumed that market clearing in the goods market determines the firms demand for labor. The nominal wage is determined by equating labor supply and labor demand as determined by the demand for goods. To complete our description of firm behavior we assume that capital is paid its value of marginal product:

$$r_t = \theta P^c_t \lambda_t K_t^{\theta-1} Q_t^{1-\theta}. \tag{4.7}$$

Equilibrium

The state variables associated with the nominal price contract will be the same as those associated with the nominal wage contract. Letting V(*s*) denote the equilibrium maximized present value of the utility stream of the representative household and letting primes denote next periods values we can write the Bellman equation associated with the household's problem as:

$$V(s) = \max\left[\ln(c) - \frac{\alpha_1}{1+\gamma}\cdot n^{1+\gamma}\cdot e - \frac{\alpha_2}{1+\tau}\cdot e^{1+\tau} + \beta E[\,V(s')\mid s]\right] \tag{4.8}$$

s.t.

$$c + x + \hat{m}/\hat{P}^c = (\hat{W}/\hat{P}^c)n\cdot e + (\hat{r}/\hat{P}^c)k + \Pi/P^c + (\hat{m} + g-1)/(\hat{P}^c g)$$

$$c = (\hat{m} + g-1)/(\hat{P}^c g)$$

$$\ln(\lambda') = \rho\ln(\lambda) + \epsilon'$$

$$\ln(g') = \eta\ln(g) + \omega'$$

$$k' = (1-\delta)k + s_1$$

$$K' = (1-\delta)K + S_1$$

$$s_i' = s_{i+1}\,,\ i = 1, 2, \cdots, I-1,$$

$$S_0' = S_{i+1,t}\,,\ i = 1, 2, \cdots, I-1,$$

$$X = \sum_{i-1}^{I} \varphi_i S_i$$

$$x = \sum_{i=1}^{I} \varphi_i s_i$$

$$c \geq 0, \ \hat{m} \geq 0, \ 0 \leq n \leq 1, \ 0 \leq e \leq 1.$$

Definition 2:

A stationary competitive equilibrium for the economy consists of a set of decision rules $c(s)$, $s_I(s)$, $\hat{m}(s)$, $n(s)$, and $e(s)$, a set of aggregate decision rules, $C(S)$, $S_i(S)$, $N(S)$, and $E(S)$, price functions, $\hat{W}(S)$ and $\hat{r}(S)$, and a value function $V(s)$ such that:

(i) the functions $V(s)$, $S_I(S)$, $N(S)$, $E(S)$, and $\hat{W}(S)$ satisfy (4.8) and $c(s)$, $s_I(s)$, $\hat{m}(s)$, $n(s)$, and $e(s)$ are the associated decision rules;

(ii) $s_I(s) = S_I(S)$, $n(s)=N(S)$, $e(s) = E(S)$, and $\hat{m}(s) = 1$ when $k=K$ and $\hat{m}=1$;

(iii) decision rules and pricing functions satisfy (4.7) and (4.8),

(iv) the functions $C(S)$ and $X(S)$ satisfy $C(S)+X(S)=Y(S)$, $\forall S$.

If the price contract is staggered, (4.7) can be written as:

(4.7′) $$\ln(Q_t) = \sum_{k=0}^{j} f_k \left[E[\ln(\tilde{Q}_t)|\Omega_{t-k}] + \gamma_{22} \cdot \left[\ln(\lambda_t) - E[\ln(\lambda_t)|\Omega_{t-k}]\right] + \gamma_{23} \cdot \left[\ln(\tilde{X}_t) - E[\ln(\tilde{X}_t)|\Omega_{t-k}]\right] \right]$$

We define the equilibrium for staggered price contracts by simply substituting (4.7′) for (4.7) in (iii) of Definition 2.

5. Calibration and Solution.

A. Parameter Choices

To study the quantitative behavior of this economy, we must assign values to the parameters of preferences and technology. We follow the procedure of choosing values based on observed features of the data. This approach to calibrating models has been widely applied in business cycle studies similar to present one. We first describe the parameters of preferences, followed by the parameters of technology and then the parameters of the forcing processes.

The discount factor, β, is set equal to .99, which implies an annual real interest rate of four percent. There are four other preference parameters in equation (2.2′) that govern the employment and hours decision. From the first-order conditions for the household we obtain the following relation between employment and hours;

$$\ln(e_t) = \frac{1}{\tau}\cdot\ln\left(\frac{\alpha_1\gamma}{\alpha_2(1+\gamma)}\right) + \frac{1+\gamma}{\tau}\cdot\ln(n_t) \tag{5.1}$$

This relationship between employment and hours can be estimated. The parameters of (5.1) were estimated using data from the Panel Study on Income Dynamics.[11] In addition to the estimated parameters in (5.1) we use two steady state relationships. As in previous business cycle studies we use the fact that, in steady state, total hours is about one third of the time endowment. Also, in our model economy the population is the labor force. In the U.S. data the employment population ratio is about 65 percent and we assume that percentage applies in our model. This gives us four relationships in four unknowns which yields values of $\alpha_1=6$, $\alpha_2=1.5$, $\gamma=2$ and $\tau=1.2$.[12]

The technology parameters are set so as to be consistent with previous studies. The parameter θ, the share of total output that is payments to capital, is set equal to .36. The depreciation rate δ is set equal to .025. The remaining parameters are those in the technology and monetary shock processes. For the technology shock, the persistence and volatility of the

---

[11] The details of this estimation are described in Bils and Cho (1990).

[12] The intertemporal substitution elasticity of labor for this specification is $(1+\gamma+\tau)/(\gamma\tau)$. The implied elasticity for our parameter values is about 1.75 which is within range of estimates by Alogoskoufis (1987) but is much smaller than that implied by the indivisible labor model and larger than most econometric estimates based on microeconomic data. See Cho and Cooley (1989) for further discussion.

shock are set at ρ=.95 and σ_ε=.009. The assumed size of the shock is on the upper bound of the range estimated by Prescott (1986). The persistence and size of the monetary shock are based on U.S. data for M1. The parameters of equation (2.7) are assumed to be η=.35 and σ_ω=.00985.[13]

Our parameter choices are summarized in the following table.[14]

β	α_1	α_2	γ	τ	θ	δ	ρ	σ_ε	η	σ_ω
.99	6	1.5	1.2	2	.36	.025	.95	.009	.35	.00985

Solution Method.

The solution method used in this paper is a variation of the method suggested by Kydland (1989) and described and applied by Cooley and Hansen (1989). It involves computing a linear quadratic approximation to the household's problem and then solving by iterating on Bellman's equation. We require that the second condition in the definition of an equilibrium hold at each iteration. The presence of nominal contracts requires additional steps to compute the conditional expectations involved in the contracts. In the case of nominal wage contracts we begin with a guess of the equilibrium decision rules for $\ln(Q_t)$ and $\ln(P_t)$. In the case of nominal price contracts we begin with guesses for investment and aggregate labor demand. A very detailed description of the solution process is available in Cho (1990).

13 In the Appendix we also report some results for a model calibrated to the monetary base. The latter shows greater persistence but less volatility than M1. In the text we restrict our discussion to results based on M1.

14 The parameters for the time-to-build technology are chosen to weight the immature capital equally. As explained above, this process plays no special role in our analysis other than to make the capital stock known as of the contracting date.

5. Results.

In this section we present the results of several experiments designed to assess the role of both wage contracts and price contracts as mechanisms by which real and nominal shocks get amplified and propagated through the economy. We consider some alternative specifications of the contract process and we introduce both monetary and technology shocks. For each alternative specification we solve for the decision rules and simulate the model economy 25 times for 115 periods. Each simulated series is detrended using the Hodrick-Prescott filter. We then compute sample statistics --standard deviations, correlations with output, autocorrelations and cross correlations-- for each case. We report some of this data in Appendix A. For ease of digestion we focus here on a few key observations that seem most useful in discriminating among the alternative specifications. We report the standard deviation of output, the ratio of the standard deviations of hours to output, consumption to output and hours to productivity.[15] In addition, we report the correlation of output with prices, output with real wages, output with productivity, and hours with productivity. The important role of the output price correlation is discussed by Kydland (1989) and Cooley and Ohanian(1990), while the importance of the hours productivity correlation is emphasized by Christiano and Eichenbaum (1990). We discuss the effects of nominal contracts in three categories: the volatility of the model economy, the correlation structure of the variables and the propagation of shocks.

Volatility.

Table 1 shows the effects of one period nominal wage and price contracts on our model economy. The first panel presents the summary statistics for the U.S. economy and the corresponding values generated by the model without contracts. Cooley and Hansen (1989) found that monetary shocks by themselves contribute almost no volatility to the economy. The same holds in this economy. Technology shocks, on the other hand, generate about 86% of the observed volatility in output in this economy. The model with both shocks is essentially the same as the model with only technology shocks. The base model does reasonably well at capturing the features of the data emphasized in this table but there are several shortcomings: i) output varies too little. ii)aggregate hours vary too little relative to output and relative to productivity. iii) the correlations between output and prices, output and real wages and output and productivity all

[15] We do not report some obvious ones like the ratio of the standard deviation of investment to output because the models don't differ very much in their ability to explain this feature of the data.

have the correct sign but are too large.

The second and third panel of Table 1 show the summary statistics for the economy with one-period nominal contracts. Table 2 shows the same statistics for an economy with two-period contracts. It is apparent that nominal contracts can play an important role in amplifying shocks. Both wage and price contracts amplify the effect of a monetary shock on output about 70 fold over the baseline model. Both kinds of contracts produce model output and aggregate hours that are significantly more volatile than observed in the U.S. data. Two-period contracts further amplify the effects of monetary shocks. For the one-period case the influence of nominal wage contracts and nominal price contracts is about the same judged by amplification. For the two-period and longer term cases wage contracts amplify monetary shocks more. It is also evident from these tables that wage and price contracts amplify technology shocks although the influence is more muted than is the impact on monetary shocks. Price contracts amplify technology shocks more than do wage contracts over the shorter term. Looking at Tables 1 and 2 shows that price contracts combined with technology shocks greatly increases the volatility of output and especially aggregate hours. Price contracts affect the volatility of aggregate hours quite substantially in the shorter contracts.

Tables 2 and 3 show the features of the simulated economy when contracts are staggered. Ideally, one would like to appeal to properties of the data to justify a particular staggering scheme for these contracts. Regrettably, the data on the nature and timing of wage contracts at the aggregate level is quite sketchy and the data on price contracts is non-existent to the best of our knowledge. Bils (1990) contains some discussion of the available data on the number and length of contracts in manufacturing. Unfortunately, it is difficult to obtain information on the number of workers covered by these agreements and these cover only a fraction of the labor force. In the absence of better data we have chosen to specify the staggered contracts so that each contract length from period one to n is accorded equal weight. We assume that a fraction of wage bargains are settled in the spot market, that is with current information. The allocation of settlements between the spot and contracting sectors is chosen to match the observed volatility of output. This provides a way of addressing the question about how much rigidity is necessary to match the features of the data. For the two-period contract model this required that 2/3 of the settlements take place in the spot sector and one sixth each in the one and two-period contracting sector. For the eight-period contract model 2/3 of settlements take place in the spot sector and the remaining third is allocated evenly over the contracts.

A comparison of Tables 1 - 3 shows the role of contract length and staggering. For nominal wage contracts the volatility of output increases greatly with contract length. Eight-period wage contracts produce a volatility of output three times that observed in the U.S. data. Staggering of the contracts reduces this volatility as more weight is placed on wage settlements based on current information. Figure 1 shows the volatility of output, consumption, new projects and investment for the eight-period wage contract model. Figure 2 shows the pattern of aggregate hours, weeks of work and average hours for the same model. The business cycle is apparent and extreme in these pictures. Figures 3 and 4 display the same information for the economy with staggered contracts. One can see that the business cycle is attenuated but still very evident.

For price contracts, the volatility of output increases as the contract length increase from one to two periods. Eight-period price contracts, however, produce output volatility that actually declines to a fraction of that observed in the U.S. data. This is a consequence of the interaction of two features of the model; the time-to-build technology and the allocation rule assumed for price contracts. The allocation rule requires output to respond only to the demand side of the market. At the same time, the time-to-build technology implies that only a small fraction of investment can respond to current shocks. Investment becomes less volatile with the longer gestation lags so the demand side of the model becomes less volatile.[16] Further, the allocation rule allows firms to decrease employment in response to positive productivity shocks thus dampening output fluctuations. As eight-period price contracts seem somewhat unlikely, we do not find these results very compelling one way or the other.

Correlation Structure

The right hand side of Tables 1, 2 and 3 show the effect of the alternative contract specifications on the correlation structure of the data generated by this artificial economy. We focus on these correlations because they have been stressed in earlier business cycle literature. We note first that the basic model without nominal contracts does not do extremely well at replicating the correlations in the data. Although the signs of the correlations are correct, the model produces correlations between output and hours, real wages and productivity that are too strong. The model also produces a strong positive correlation between productivity and hours, a

[16] With one and two-period contracts we assume two period gestation lags while with eight-period contracts we use eight period gestation lags. We varied the length for computational reasons, but the sensitivity of the price contract to this specification was surprising.

defect that is discussed and explored by Christiano and Eichenbaum (1990).

Several general conclusions emerge from comparing the features of the various contracting models to the data. First, models with only monetary shocks cannot reproduce these features of the data. In the wage contracting economies with only monetary shocks, all four correlations have the wrong sign. In price contracting economies with only money shocks three out of the four have the wrong sign. Thus, while contracts do indeed help to amplify monetary shocks, they generate a correlation structure that is inconsistent with the facts of the U.S. economy.

Next, we note that the nominal price contracts produce a correlation structure that is inconsistent with the features of the data. These contracts produce correlations between output and real wages and output and productivity that are opposite in sign from one another. Perhaps most importantly the latter correlation and the correlation of hours and productivity are large and negative, contrary to the correlations in the data.[17] Many advocates of the nominal price contracting view have stressed the fact that monetary shocks with price contracts imply a postive correlation between real wages and monetary shocks or , what amounts to the same thing, between real wages and output (eq. see Kretzmer (1989), Keane (1990) and King(1990)). This is born out by the results in Tables 1-3, but the same tables show the drawback of focusing on a single correlation because the correlations between output and productivity or productivity and hours are clearly at odds with the data.

In contrast, the wage contracting economy driven by technology shocks seems to fit the correlation structure of the data pretty well. One effect of the contracts is to attenuate the correlations between output and the real wage and productivity, and between hours and productivity. Moreover, this effect seems more pronounced the longer the terms of the contract. Staggered wage contracts with both shocks operating seem to match up with the data quite well. They produce a positive correlation between real wages and productivity and the reduce the correlation between productivity and hours to zero. This finding answers the question raised by Christiano and Eichenbaum (1990) regarding the ability of real business cycle models to reproduce this feature of the data.

Propagation of Shocks

Finally, we consider how nominal contracts propagate shocks in this model economy. To

[17] This is a traditional shortcoming of Keynesian models.

address this issue we plot the impulse response functions for innovations in money and technology shocks for several key variables. These results are presented in Figure 5 where we plot the response of macroeconomic aggregates for both the price contracting economy, the wage contracting economy and the economy without contracts. The functions plotted are based on the decision rules for the eight-period contract model.

The left hand panels show the response to innovations in the technology shock, while the right hand panel shows the response to innovations in the monetary shock. Looking first at the technology shocks, it is clear that the model propagates these even in the absence of nominal contracts (the solid line). Nominal wage contracts increase that propagation somewhat but not dramatically. In contrast, the role of nominal price contracts is to offset the effects of technology shocks. This is in keeping with the properties of the model discussed in Section 2.

The response to monetary shocks is quite different. The right-hand panels show that the basic model does not propagate monetary shocks very much at all. The introduction of nominal wage contracts makes a huge difference. With them, monetary shocks are propagated very strongly throughout the model economy. In this eight-period case the price contracts propagate monetary shocks but only very slightly.[18] This is in contrast to the one-period and two-period price contracting models which clearly propagate monetary shocks. The role of the time-to-build technology is seen clearly in these responses.

6. Concluding Remarks.

We have explored the quantitative implications of two types of nominal rigidities in a relatively simple equilibrium business cycle model. In contrasting these models we place a heavy emphasis on their ability to replicate particular features of the aggregate U.S. data. Based on those comparisons we are lead to several conclusions:

- Nominal contracts can play an important role in amplifying and propagating shocks, especially monetary shocks.
- Monetary shocks, when propagated by nominal contracts produce data with properties that are inconsistent with U.S. data.
- Nominal price contracts produce data with properties that are inconsistent with the features of the U.S. data.

[18] King (1990) introduces through a quantity equation and studies twelve-period contracts. In that setting price contracts propagate monetary shocks a lot.

- Nominal wage contracts acting with both technology shocks and monetary shocks produce data that match the features of the U.S. business cycle quite well. These models appear to resolve some existing problems with real business cycle models.

These observations stand in rather sharp contrast to several recent explorations of the macroeconomic implications of nominal rigidities.

Much of the new Keynesian literature has focused attention on the importance of sticky goods prices as propagation mechanisms for monetary shocks. The empirical evidence in favor of that view is very limited and unconvincing. The empirical evidence from the model economies studied in this paper is inconsistent with sticky prices being an important factor. King (1990) finds broad similarities between nominal wage contract and nominal price contracts in an explicit quantitative equilibrium model like the one considered here. His results seem to favor slightly the nominal price contract model. There are two notable difference between this study and his. This study considers both monetary shocks and technology shocks while his considers only the former. Secondly, we focus our attention more sharply on the ability of the models to produce volatility and correlations like those observed in the data. King's analysis is more detailed examination of the models ability to replicate distributed lag features of the relationship between macroeconomic aggregates and monetary shocks.

One reason for the poor performance of the price contracting arrangements in our artificial economy is that we have placed severe constraints on firm behavior. It may be that one has to introduce inventories to allow firms to buffer unanticipated demand shocks in order to produce a realistic view of price contracts. Such a model might also reconcile some of the observed puzzles about the relative volatility of inventories and output.

REFERENCES

Akerlof, G. and J. Yellen (1985), "A Near-rational Model of the Business Cycle with Wage and Price Inertia," *Quarterly Journal of Economics* 100, pp. 823-38.

Alogoskoufis, G.S. (1987), "On Intertemporal Substitution and Aggregate Labor Supply," *Journal of Political Economy* 95, pp. 938-960.

Bils, M. (1990), "Indexation and Contract Length in Unionized U.S. Manufacturing," reproduced, The Hoover Institution, July.

Bils, M., and J.O. Cho (1990), "Utilization of Labor Over the Business Cycle," in progress.

Blinder, A.S. and N.G. Mankiw (1984), "Aggregation and Stabilization Policy in a Multi-contract Economy," *Journal of Monetary Economics* 13, pp. 67-86.

Carlton, Dennis W. (1986), "The Rigidity of Prices," *American Econoic Review*, 76, 637-58.

Cho, J.O. (1990), "Money, Nominal Contracts, and the Business Cycle: I. One-period Contract Case," Discussion Paper, Queen's University.

Cho, J.O. and T.F. Cooley (1989), "Employment and Hours Over the Business Cycle," Rochester Center for Economic Research Working Paper No. 132.

Christiano, L.J. and M. Eichenbaum (1988), "Is Theory Really Ahead of Measurement? Current Real Business Cycle Theory and Aggregate Labor Market Fluctuations," Federal Reserve Bank of Minneapolis Working Paper No. 412.

Cooley, T.F. and G.D. Hansen (1989), "Inflation Tax in a Real Business Cycle Model," *American Economic Review* 79, pp. 733-748.

Cooley, T.F. and L. Ohanian (1989), "The Cyclical Behavior of Prices," reproduced, University of Rochester.

Fischer, S. (1977), "Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule," *Journal of Political Economy* 85.

Gray, J.A. (1976), "Wage Indexation: A Macroeconomic Approach," *Journal of Monetary Economics* 2, pp. 221-235.

Gordon, R.J. (1990), " What is New-Keynesian Economics?", *The Journal of Economic Literature*, XXVIII,3 1115-71.

Hansen, G.D. (1985), "Indivisible Labor and the Business Cycle," *Journal of Monetary Economics* 16, pp. 309-28.

Keane, M.P. (1990), "Nominal Contracting Theories of Unemployment: Evidence from Panel Data," reproduced, University of Minnesota.

King, R.G. (1990), "Money and Business Cycles," reproduced.

Kretzmer, P. (1989), ""The Cross-Industry Effects of Unanticipated Money in an Equilibrium Business Cycle Model," *Journal of Monetary Economics*, 11, 73-88.

Kydland, F.E. (1987), "The Role of Money in a Competitive Model of Business Fluctuations," reproduced, Carnegie-Mellon University.

Kydland, F.E. and E.C. Prescott (1982), "Time to Build and Aggregate Fluctuations," *Econometrica*, 50.

Lucas, R.E., Jr. (1987), *Models of Business Cycles*, New York: Basil Blackwell.

Lucas, R.E., Jr. (1990), "The Effects of Monetary Shock When Prices are Set in Advance," reproduced.

Mankiw, N.G. (1985), "Small Menu Costs and Large Business Cycles: A Macroeconomic Model of Monopoly," *Quarterly Journal of Economics* 100, pp. 529-39.

Parkin, M. (1986), "The Output Inflation Trade-off When Prices are Costly to Change," *Journal of Political Economy* 94, pp. 200-24.

Prescott, E.C. (Fall 1986), "Theory Ahead of Business Cycle Measurement," Federal Reserve Bank of Minneapolis *Quarterly Review* 10, pp. 9-22.

Rotemberg, J.J. (1986), "The New Keynesian Microfoundations," *NBER Macroeconomics Annual* 1, pp. 69-104.

Taylor, John (1979), "Staggered Price Setting in a Macro Model," *American Economic Review*, 69, 108-113.

________(1980), "Aggregate Dynamics and Staggered Contracts," *Journal of Political Economy*, 88, 1-24.

Table 1
One Period Contract Models

Base Model Without Contracts

	Standard Deviations				Correlations			
	Y	Q/Y	C/Y	Q/Py	Corr (Y,P)	Corr (Y,Rw)	Corr (Y,Py)	Corr (Py,Q)
Data	1.74	1.03	.466	1.65	-.53	0.4	0.56	.14
Monetary Shocks	.03	1.3	10	2	-.15	-.24	-.24	-.31
Technology Shocks	1.51	0.46	0.42	0.78	-.86	.89	.95	.91
Basic Model Both Shocks	1.57	0.46	0.46	0.81	-.26	.95	.95	.90

One Period Nominal Wage Contracts

	Standard Deviations				Correlations			
	Y	Q/Y	C/Y	Q/Py	Corr (Y,P)	Corr (Y,Rw)	Corr (Y,Py)	Corr (Py,Q)
Monetary Shocks	2.07	1.59	.246	2.6	.44	-.85	-.92	-.95
Technology Shocks	1.79	.71	.318	1.58	-.80	.78	.73	.42
Both Shocks	2.80	1.27	0.28	2.41	.14	-.31	-.31	-.64

One Period Nominal Price Contracts

	Standard Deviations				Correlations			
	Y	Q/Y	C/Y	Q/Py	Corr (Y,P)	Corr (Y,Rw)	Corr (Y,Py)	Corr (Py,Q)
Monetary Shocks	2.04	1.59	.25	2.62	.54	.36	-.92	-.95
Technology Shocks	2.40	1.65	.25	1.95	-.49	.40	-.58	-.84
Both Shocks	3.12	1.63	0.25	2.15	.23	.38	-.68	-.86

Table 2
Two Period Contract Models

Two Period Nominal Wage Contracts

	Standard Deviations				Correlations			
	Y	Q/Y	C/Y	Q/Py	Corr (Y,P)	Corr (Y,Rw)	Corr (Y,Py)	Corr (Py,Q)
Monetary Shocks	3.04	1.6	0.22	2.62	.48	-.67	-.92	-.96
Technology Shocks	2.05	0.80	0.37	2.02	-.83	.68	.62	.29
Both Shocks	3.56	1.40	0.19	2.59	.33	-.59	-.59	-.79
Staggered Contract	1.73	0.86	0.21	1.60	0.20	0.34	0.49	-.03

Two Period Nominal Price Contracts

	Standard Deviations				Correlations			
	Y	Q/Y	C/Y	Q/Py	Corr (Y,P)	Corr (Y,Rw)	Corr (Y,Py)	Corr (Py,Q)
Monetary Shocks	2.24	1.61	.18	2.61	.68	.33	-.93	-.95
Technology Shocks	3.69	1.78	0.07	2.6	-.57	.73	-.81	-.93
Both Shocks	3.91	1.75	0.12	2.18	.34	.45	-.85	-.93
Staggered Contracts	1.69	1.29	.29	1.55	.34	.54	.01	-.61

Table 3
Eight Period Contract Models

Eight Period Nominal Wage Contracts

	Standard Deviations				Correlations			
	Y	Q/Y	C/Y	Q/Py	Corr (Y,P)	Corr (Y,Rw)	Corr (Y,Py)	Corr (Py,Q)
Both Shocks Not Staggered	5.07	1.63	0.32	2.33	-.15	-.80	-.80	-.90
Both Shocks Staggered	1.79	1.02	0.52	1.66	-.05	.26	.26	-.02

Eight Period Nominal Price Contracts

	Standard Deviations				Correlations			
	Y	Q/Y	C/Y	Q/Py	Corr (Y,P)	Corr (Y,Rw)	Corr (Y,Py)	Corr (Py,Q)
Both Shocks Not Staggered	1.21	2.77	0.29	1.46	.03	.91	-.77	-.94
Both Shocks Staggered	.86	.65	0.60	0.50	-.22	.69	.85	-.65

Figure 1

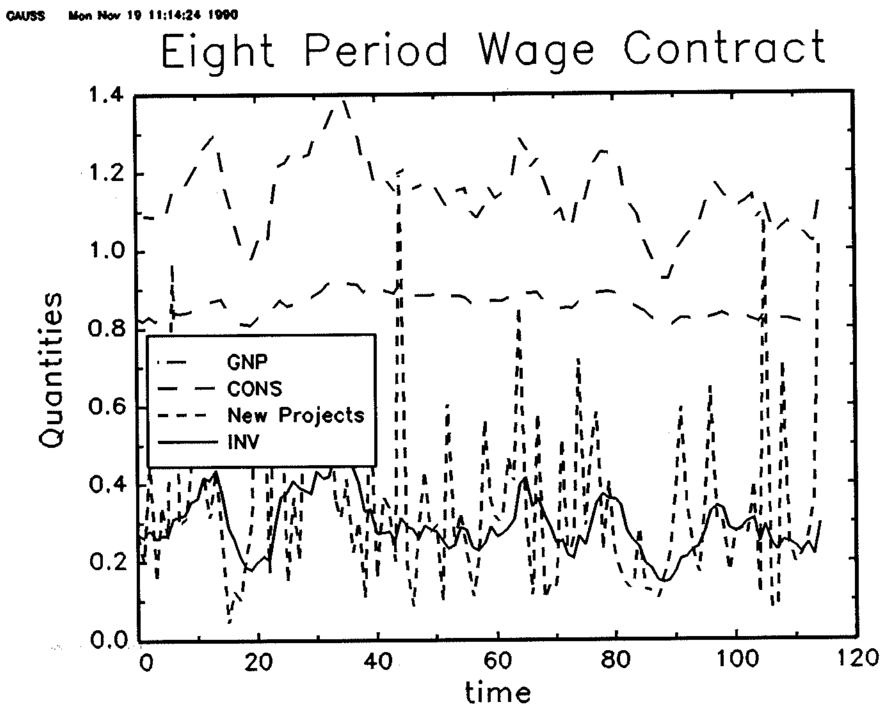


Figure 2

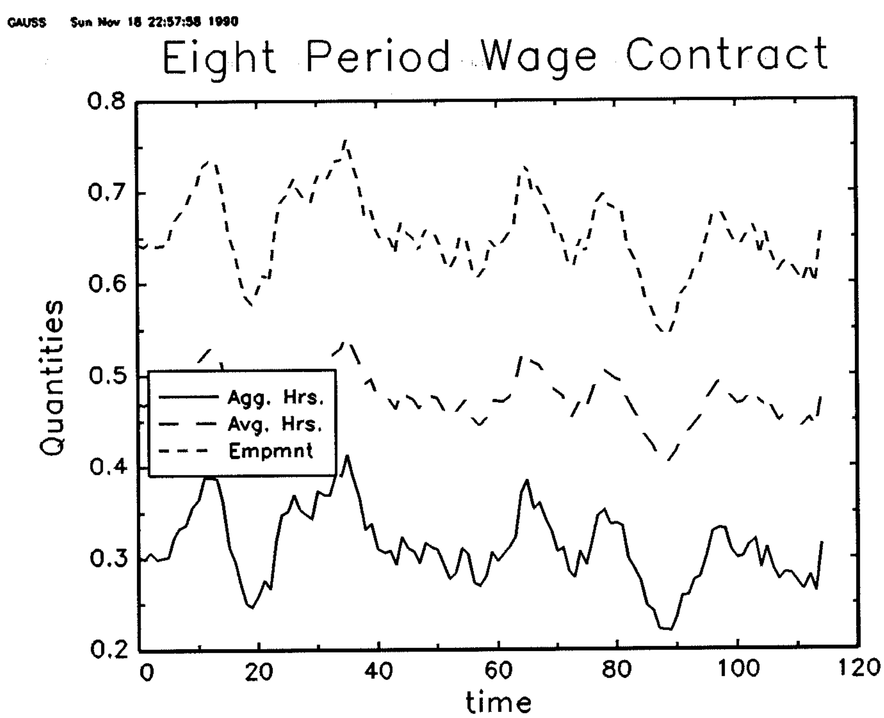


Figure 3

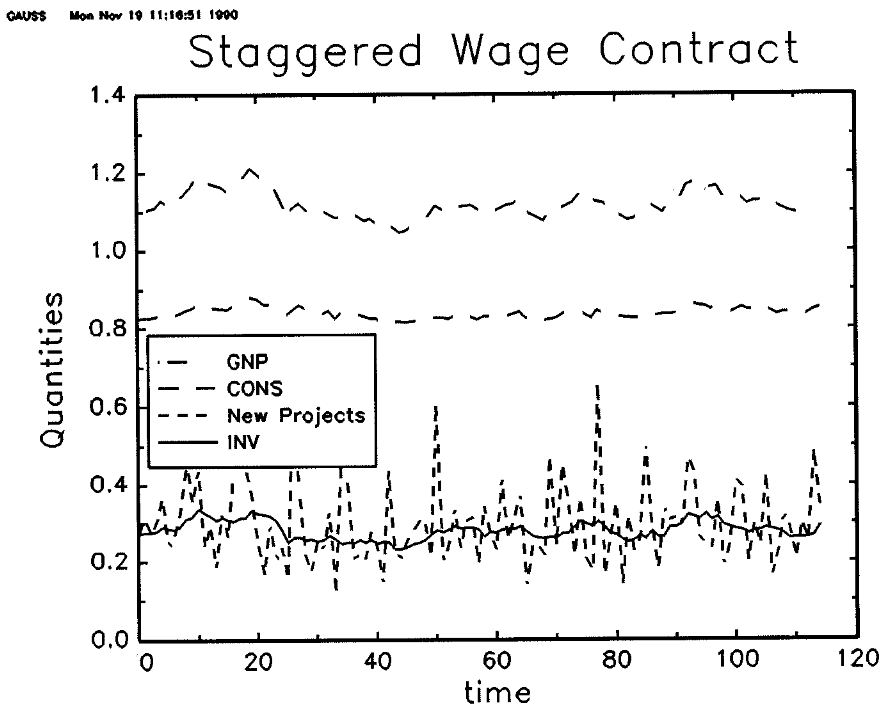


Figure 4

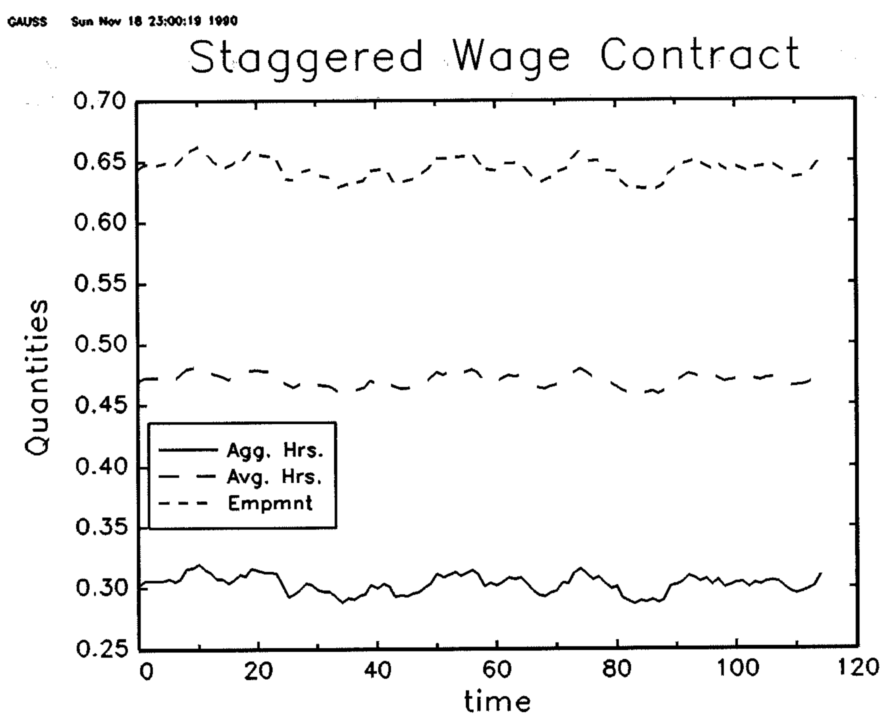


Figure 5
Impulse Response Functions

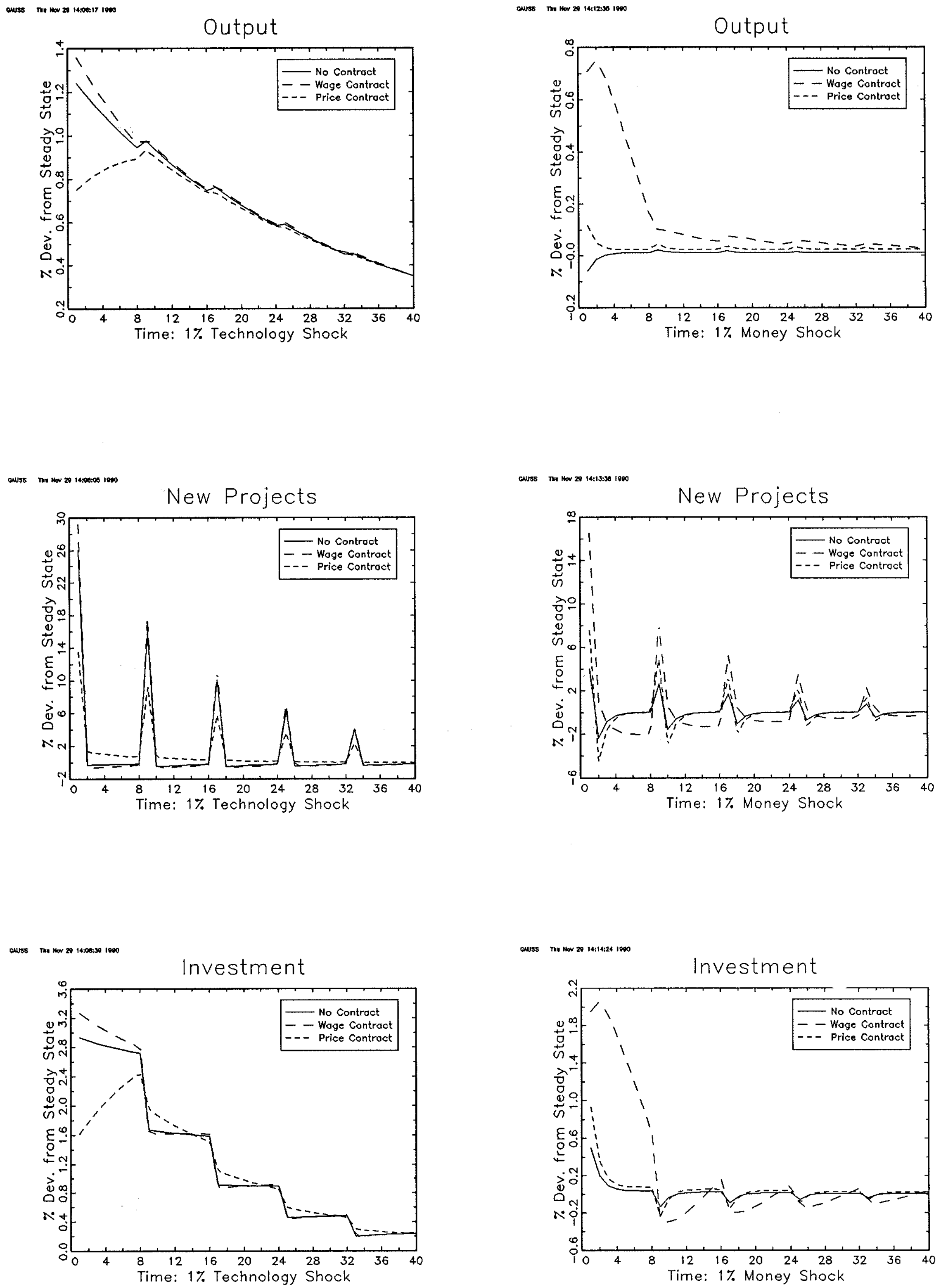
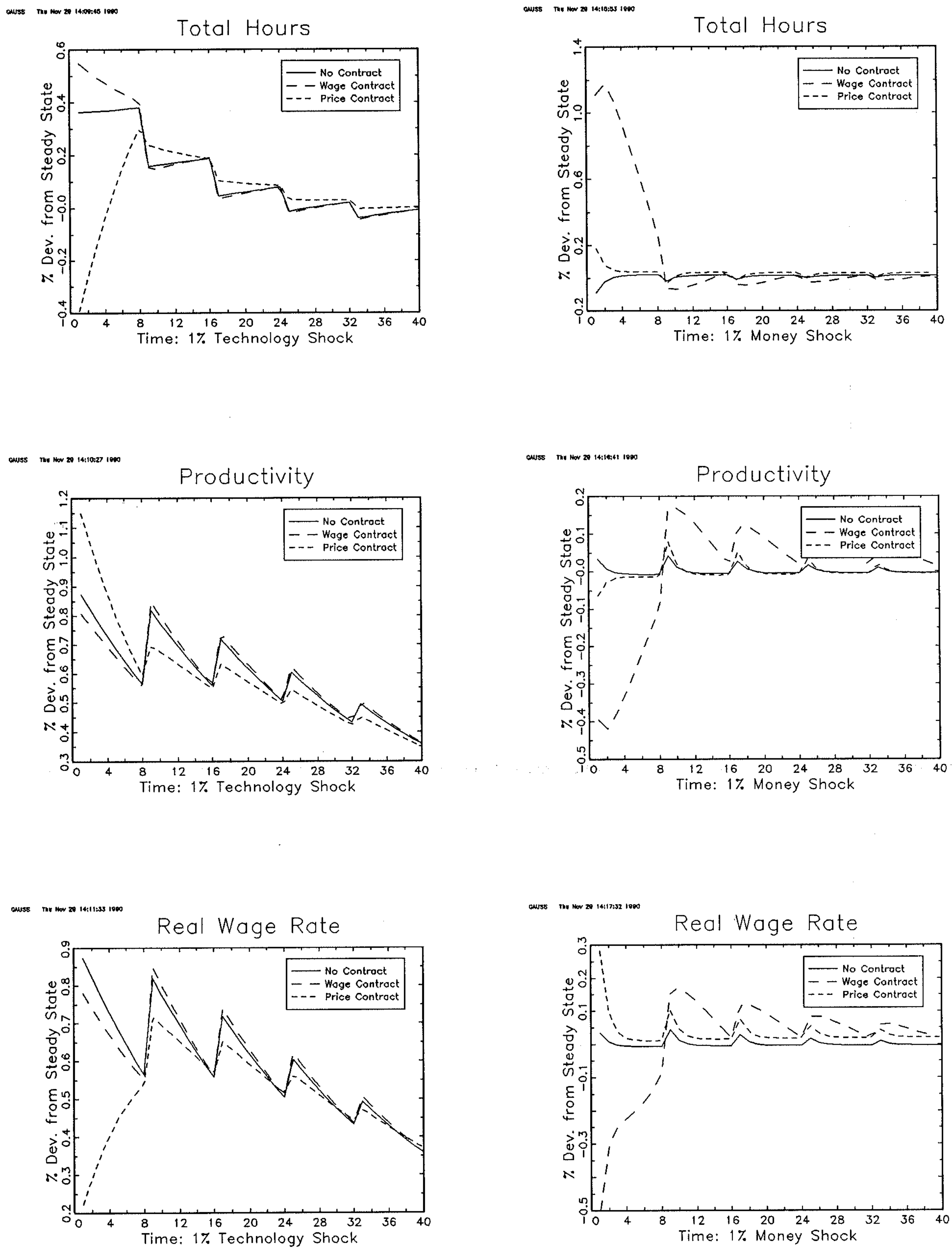


Figure 5 Continued



APPENDIX A

Table A1. Summary Statistics from Quarterly U.S. Data

A. Standard Deviations

Y	C	X	K	Q	N	E	Pdty
1.74	.81	8.49	.38	1.80	.46	1.50	1.09

W	Rw	R	RRCPI	RRGD	CPI	GD
1.00	.99	1.31	1.20	.98	1.60	.98

B. Correlations with Output

Y	C	X	K	Q	N	E	Pdty
1.00	.65	.91	.28	.87	.76	.81	.56

W	Rw	R	RRCPI	RRGD	CPI	GD
-.45	.40	.33	.35	.46	-.53	-.53

Note: Y = GNP, C = consumption of nondurables and services plus the flow of services from durables constructed by Lawrence Christiano, X = gross private domestic investment, K = capital stock constructed by Lawrence Christiano, Q = total hours of all person, H = hours per person, E= total number of employed person, Pdty = output divided by total hours, W = nominal compensation per hour, Rw = real compensation per hour, R = 90 day tbill rate, RRCPI = ex post real rate using CPI, RRGD = ex post real rate using GNP deflator, CPI = consumer price index, GD = GNP deflator. All series except consumption and capital stock were taken from Citibase database. All series except interest rates are logged, and all series are seasonally adjusted and detrended using the Hodrick-Prescott filter. Sample periods: 1955.3 - 1984.1.

Table A2. Only Money Shock (M1)

	No Contract		Wage(1)		Price(1)		Wage(2)		Price(2)	
	SD	CR	SD	CR	SD	CR	SD	CR	SD	CR
Y	.03	1.00	2.07	1.00	2.04	1.00	3.04	1.00	2.24	1.00
	(.01)	(.00)	(.45)	(.00)	(.45)	(.00)	(.65)	(.00)	(.50)	(.00)
C	.30	.91	.51	.45	.51	-.09	.67	.75	.41	-.23
	(.07)	(.19)	(.16)	(.09)	(.15)	(.11)	(.14)	(.15)	(.12)	(.11)
X	.80	-.92	7.57	.95	8.23	.95	11.32	.96	9.14	.95
	(.17)	(.19)	(1.62)	(.19)	(1.81)	(.19)	(2.42)	(.20)	(2.02)	(.19)
K	.06	.42	.62	-.12	.62	-.15	.55	-.40	.59	-.24
	(.02)	(.11)	(.19)	(.09)	(.17)	(.11)	(.13)	(.10)	(.17)	(.10)
Q	.04	.66	3.30	.96	3.25	.96	4.88	.96	3.60	.96
	(.01)	(.15)	(.71)	(.20)	(.71)	(.19)	(1.04)	(.20)	(.79)	(.20)
N	.04	.66	1.57	.96	1.55	.96	2.32	.96	1.71	.96
	(.01)	(.15)	(.34)	(.20)	(.34)	(.19)	(.50)	(.20)	(.38)	(.20)
E	.02	.66	1.73	.96	1.70	.96	2.56	.96	1.89	.96
	(.00)	(.15)	(.37)	(.20)	(.37)	(.19)	(.55)	(.20)	(.42)	(.20)
Py	.02	-.24	1.26	-.92	1.24	-.92	1.86	-.95	1.38	-.93
	(.01)	(.11)	(.27)	(.19)	(.27)	(.19)	(.40)	(.20)	(.30)	(.19)
W	1.78	-.15	1.85	.13	6.31	.50	1.60	.18	5.47	.55
	(.48)	(.12)	(.15)	(.03)	(1.81)	(.11)	(.39)	(.04)	(1.58)	(.12)
Rw	.02	-.24	1.26	-.92	6.38	.36	1.86	-.95	4.89	.33
	(.01)	(.12)	(.27)	(.19)	(1.92)	(.08)	(.40)	(.20)	(1.63)	(.07)
R	1.20	-.11	1.77	.02	2.10	-.07	1.90	-.15	2.01	-.22
	(.26)	(.11)	(.39)	(.10)	(.46)	(.06)	(.41)	(.07)	(.45)	(.08)
RR	.00	.03	.08	.92	.08	.92	.12	.95	.09	.93
	(.00)	(.05)	(.02)	(.19)	(.02)	(.19)	(.03)	(.19)	(.02)	(.19)
P	1.76	-.15	2.00	.44	2.12	.54	1.73	.48	2.04	.68
	(.47)	(.12)	(.50)	(.10)	(.45)	(.17)	(.38)	(.10)	(.46)	(.14)

Note: (1) SD is standard deviations and CR is correlations with output.
(2) Y = GNP, C = consumption, X = investment, K = capital stock, Q = total hours, N = hours per person, E = total number of employed person, Pdty = productivity, W = nominal wage rate, Rw = real wage rate, R = nominal rental rate, RR = real rental rate, P = price level. All series except interest rates are logged and detrended using Hodrick-Prescott filter. The standard deviations are in percentage term.
(3) The money growth shock is assumed to follow:

$$\ln(g_{t+1}) = .35\ln(g_t) + \omega_{t+1}, \text{ where } \omega_{t+1} \sim \text{i.i.d. } n(.65\ln(1.015), .00985^2).$$

Table A3. Only Money Shock (MB)

	No Contract		Wage(1)		Price(1)		Wage(2)		Price(2)	
	SD	CR	SD	CR	SD	CR	SD	CR	SD	CR
Y	.04	1.00	1.52	1.00	2.32	1.00	2.46	1.00	2.88	1.00
	(.00)	(.00)	(.32)	(.00)	(.50)	(.00)	(.53)	(.00)	(.63)	(.00)
C	.35	.93	.36	.46	.55	-.06	.56	.72	.35	-.35
	(.01)	(.19)	(.10)	(.10)	(.14)	(.08)	(.12)	(.15)	(.09)	(.12)
X	.92	-.93	5.56	.95	9.33	.95	9.17	.96	11.70	.96
	(.21)	(.19)	(1.20)	(.19)	(2.02)	(.19)	(1.97)	(.20)	(2.58)	(.20)
K	.07	.44	.44	-.14	.66	-.19	.45	-.40	.64	-.35
	(.01)	(.11)	(.12)	(.10)	(.17)	(.09)	(.10)	(.11)	(.15)	(.09)
Q	.06	.80	2.42	.96	3.72	.96	3.95	.96	4.64	.96
	(.01)	(.17)	(.52)	(.20)	(.80)	(.20)	(.85)	(.20)	(1.02)	(.20)
N	.03	.80	1.15	.96	1.77	.96	1.88	.96	2.21	.96
	(.00)	(.17)	(.25)	(.20)	(.38)	(.20)	(.40)	(.20)	(.49)	(.20)
E	.03	.80	1.27	.96	1.95	.96	2.07	.96	2.43	.96
	(.00)	(.17)	(.27)	(.20)	(.42)	(.20)	(.44)	(.20)	(.54)	(.20)
Py	.03	-.39	.92	-.93	1.43	-.92	1.50	-.96	1.78	-.94
	(.00)	(.12)	(.20)	(.19)	(.31)	(.19)	(.32)	(.19)	(.39)	(.19)
W	1.58	-.17	1.73	-.10	6.30	.41	1.70	-.11	4.46	.5o
	(.42)	(.11)	(.46)	(.03)	(1.68)	(.08)	(.44)	(.03)	(1.13)	(.11)
Rw	.03	-.39	.92	-.93	6.60	.30	1.50	-.96	4.23	.39
	(.00)	(.12)	(.20)	(.18)	(1.80)	(.07)	(.32)	(.19)	(1.15)	(.09)
R	.86	-.21	1.13	.33	1.57	.27	1.15	.14	1.23	.07
	(.19)	(.10)	(.25)	(.09)	(.34)	(.08)	(.25)	(.08)	(.26)	(.13)
RR	.00	.20	.06	.93	.09	.93	.09	.95	.11	.94
	(.00)	(.08)	(.01)	(.19)	(.02)	(.19)	(.02)	(.19)	(.02)	(.19)
P	1.55	-.17	1.68	.12	1.82	.22	1.54	.14	1.64	.43
	(.42)	(.10)	(.43)	(.04)	(.44)	(.05)	(.39)	(.04)	(.43)	(.10)

Note: (1) See (1) and (2) in Table A2.
(2) The money growth shock is assumed to follow:

$$\ln(g_{t+1}) = .67\ln(g_t) + \omega_{t+1}, \text{ where } \omega_{t+1} \sim \text{i.i.d. } n(.33\ln(1.15), .00595^2).$$

Table A4. Only Technology Shock

	No Contract		Wage(1)		Price(1)		Wage(2)		Price(2)	
	SD	CR	SD	CR	SD	CR	SD	CR	SD	CR
Y	1.51	1.00	1.79	1.00	2.40	1.00	2.05	1.00	3.69	1.00
	(.36)	(.00)	(.39)	(.00)	(.52)	(.00)	(.46)	(.00)	(.80)	(.00)
C	.63	.85	.57	.80	.59	.49	.76	.83	.26	.52
	(.15)	(.18)	(.14)	(.17)	(.15)	(.11)	(.18)	(.17)	(.07)	(.13)
X	4.66	.95	5.71	.95	8.66	.95	6.66	.95	14.09	.96
	(1.09)	(.19)	(1.24)	(.19)	(1.89)	(.19)	(1.52)	(.19)	(3.05)	(.20)
K	.42	-.07	.51	-.07	.68	-.15	.51	-.13	.72	-.42
	(.11)	(.09)	(.13)	(.08)	(.17)	(.09)	(.13)	(.08)	(.18)	(.11)
Q	.69	.94	1.28	.88	3.96	.88	1.64	.89	6.57	.94
	(.16)	(.19)	(.27)	(.18)	(.86)	(.18)	(.36)	(.18)	(1.42)	(.19)
N	.33	.94	.61	.88	1.89	.88	.78	.89	3.13	.94
	(.08)	(.19)	(.13)	(.18)	(.41)	(.18)	(.17)	(.18)	(.68)	(.19)
E	.36	.94	.67	.88	2.08	.88	.86	.89	3.44	.94
	(.08)	(.19)	(.14)	(.18)	(.45)	(.18)	(.19)	(.18)	(.75)	(.19)
Py	.88	.95	.81	.73	2.03	-.58	.81	.62	3.05	-.86
	(.21)	(.19)	(.19)	(.15)	(.44)	(.13)	(.21)	(.13)	(.66)	(.18)
W	.45	.95	.36	.48	5.45	.40	.47	-.15	2.95	.71
	(.10)	(.19)	(.08)	(.13)	(1.79)	(.09)	(.11)	(.10)	(.63)	(.15)
Rw	.88	.95	.81	.73	5.94	.40	.81	.62	3.08	.73
	(.21)	(.19)	(.19)	(.16)	(1.94)	(.09)	(.21)	(.13)	(.66)	(.15)
R	.45	.93	.60	.39	.96	.43	.65	.21	.18	.90
	(.11)	(.19)	(.15)	(.09)	(.31)	(.10)	(.15)	(.06)	(.04)	(.18)
RR	.06	.35	.07	.93	.09	.92	.08	.94	.14	.95
	(.01)	(.09)	(.01)	(.19)	(.02)	(.19)	(.02)	(.19)	(.03)	(.19)
P	.51	-.86	.57	-.80	.59	-.49	.76	-.83	.26	-.51
	(.42)	(.18)	(.14)	(.17)	(.15)	(.11)	(.18)	(.17)	(.07)	(.13)

Note: (1) See (1) and (2) of Table A2.
(2) The technology shock is assumed to follow:

$$\ln(g_{t+1}) = .95\ln(\lambda_t) + \epsilon_{t+1}, \text{ where } \epsilon_{t+1} \sim \text{i.i.d. } n(0,.009^2).$$

Table A5. Both Shocks Without Staggering (M1)

	No Contract		Wage(1)		Price(1)		Wage(2)		Price(2)	
	SD	CR	SD	CR	SD	CR	SD	CR	SD	CR
Y	1.57	1.00	2.80	1.00	3.12	1.00	3.56	1.00	3.91	1.00
	(.38)	(.00)	(.60)	(.00)	(.68)	(.00)	(.80)	(.00)	(.85)	(.00)
C	.72	.79	.78	.63	.78	.25	.66	.64	.48	.10
	(.17)	(.17)	(.19)	(.13)	(.22)	(.08)	(.16)	(.14)	(.13)	(.63)
X	4.92	.94	9.64	.95	11.84	.94	12.75	.96	15.23	.96
	(1.19)	(.19)	(2.08)	(.19)	(2.60)	(.19)	(2.85)	(.19)	(3.31)	(.20)
K	.44	-.05	.80	-.10	.92	-.15	.75	-.28	.87	-.33
	(.13)	(.08)	(.21)	(.09)	(.24)	(.11)	(.18)	(.09)	(.20)	(.08)
Q	.72	.94	3.56	.88	5.09	.91	4.98	.92	6.83	.94
	(.17)	(.19)	(.78)	(.18)	(1.11)	(.19)	(1.11)	(.19)	(1.49)	(.19)
N	.34	.94	1.69	.88	2.42	.91	2.37	.92	3.25	.94
	(.08)	(.19)	(.37)	(.18)	(.53)	(.19)	(.53)	(.19)	(.71)	(.19)
E	.38	.94	1.86	.88	2.66	.91	2.61	.92	3.58	.94
	(.09)	(.19)	(.41)	(.18)	(.58)	(.19)	(.58)	(.19)	(.78)	(.19)
Py	.89	.95	1.48	-.31	2.37	-.68	1.92	-.59	3.13	-.85
	(.22)	(.19)	(.32)	(.13)	(.51)	(.15)	(.43)	(.15)	(.68)	(.18)
W	1.81	.21	1.81	.14	8.87	.43	1.62	.30	6.15	.53
	(.49)	(.17)	(.44)	(.09)	(2.71)	(.09)	(.42)	(.10)	(1.61)	(.12)
Rw	.89	.95	1.48	-.31	8.46	.38	1.92	-.59	5.71	.45
	(.22)	(.19)	(.32)	(.13)	(2.51)	(.08)	(.43)	(.15)	(1.63)	(.10)
R	1.28	.09	1.88	.09	2.35	.07	.66	-.08	1.96	-.07
	(.28)	(.11)	(.41)	(.08)	(.51)	(.07)	(.35)	(.08)	(.42)	(.09)
RR	.06	.93	.11	.92	.12	.92	.14	.94	.15	.94
	(.01)	(.19)	(.02)	(.19)	(.03)	(.19)	(.03)	(.19)	(.03)	(.19)
P	1.82	-.26	2.03	.14	2.18	.23	1.81	.33	2.03	.34
	(.49)	(.17)	(.46)	(.11)	(.49)	(.09)	(.45)	(.11)	(.46)	(.13)

Note: (1) See (1) and (2) in Table A2.
(2) The money growth and technology shocks are assumed to follow:

$$\ln(g_{t+1}) = .35\ln(g_t) + \omega_{t+1}, \text{ where } \omega_{t+1} \sim \text{i.i.d. } n(.65\ln(1.015), .00985^2).$$

$$\ln(\lambda_{t+1}) = .95\ln(\lambda_t) + \epsilon_{t+1}, \text{ where } \epsilon_{t+1} \sim \text{i.i.d. } n(0, .009^2).$$

Table A6. Both Shocks Without Staggering (MB)

	No Contract		Wage(1)		Price(1)		Wage(2)		Price(2)	
	SD	CR	SD	CR	SD	CR	SD	CR	SD	CR
Y	1.52	1.00	2.41	1.00	3.22	1.00	3.16	1.00	4.31	1.00
	(.36)	(.00)	(.53)	(.00)	(.69)	(.00)	(.70)	(.00)	(.94)	(.00)
C	.79	.57	.70	.68	.76	.23	.63	.65	.40	-.01
	(.18)	(.15)	(.16)	(.14)	(.21)	(.08)	(.16)	(.14)	(.11)	(.08)
X	4.93	.89	8.16	.95	12.26	.94	11.21	.95	16.95	.96
	(1.16)	(.18)	(1.80)	(.19)	(2.64)	(.19)	(2.47)	(.19)	(3.71)	(.20)
K	.44	-.06	.68	-.09	.91	-.18	.66	-.27	.91	-.38
	(.13)	(.08)	(.16)	(.06)	(.23)	(.09)	(.16)	(.11)	(.20)	(.10)
Q	.70	.93	2.77	.85	5.23	.91	4.24	.90	7.45	.94
	(.16)	(.19)	(.60)	(.18)	(1.12)	(.19)	(.91)	(.18)	(1.64)	(.19)
N	.33	.93	1.32	.85	2.49	.91	2.02	.90	3.55	.94
	(.08)	(.19)	(.29)	(.18)	(.53)	(.19)	(.44)	(.18)	(.78)	(.19)
E	.37	.93	1.45	.85	2.74	.91	2.22	.90	3.90	.94
	(.09)	(.19)	(.32)	(.18)	(.59)	(.19)	(.48)	(.18)	(.86)	(.19)
Py	.86	.94	1.27	-.04	2.41	-.70	1.69	-.45	3.33	-.86
	(.21)	(.19)	(.28)	(.12)	(.53)	(.16)	(.36)	(.17)	(.73)	(.18)
W	2.78	.09	1.76	.03	8.31	.35	1.71	.05	4.74	.53
	(.73)	(.23)	(.45)	(.15)	(2.52)	(.08)	(.42)	(.10)	(1.13)	(.12)
Rw	.86	.94	1.27	-.04	7.80	.39	1.69	-.45	5.13	.56
	(.21)	(.19)	(.28)	(.12)	(2.34)	(.09)	(.36)	(.17)	(1.18)	(.12)
R	1.48	.10	1.27	.30	1.73	.32	1.10	.19	1.21	.14
	(.33)	(.11)	(.28)	(.09)	(.41)	(.07)	(.24)	(.09)	(.26)	(.09)
RR	.06	.92	.09	.93	.12	.93	.12	.94	.17	.94
	(.01)	(.19)	(.02)	(.19)	(.03)	(.19)	(.03)	(.19)	(.04)	(.19)
P	2.79	-.19	1.78	-.13	1.93	.03	1.67	.02	1.72	.22
	(.77)	(.22)	(.47)	(.16)	(.46)	(.11)	(.44)	(.13)	(.44)	(.11)

Note: (1) See (1) and (2) of Table A2.
(2) Money growth and technology shocks are asumed to follow:

$$\ln(g_{t+1}) = .671\ln(g_t) + \omega_{t+1}, \text{ where } \omega_{t+1} \sim \text{i.i.d. } n(.33\ln(1.15), .00595^2).$$

$$\ln(\lambda_{t+1}) = .95\ln(\lambda_t) + \epsilon_{t+1}, \text{ where } \epsilon_{t+1} \sim \text{i.i.d. } n(0, .009^2).$$

Table A7. Two Period Staggered Contracts (M1)

	No Contract		Wage(2)		Price(2)	
	SD	CR	SD	CR	SD	CR
Y	1.49	1.00	1.73	1.00	1.69	1.00
	(.34)	(.00)	(.40)	(.00)	(.40)	(.00)
C	.59	.74	.36	.51	.49	.28
	(.13)	(.16)	(.09)	(.11)	(.12)	(.12)
X	4.65	.93	6.29	.95	6.32	.94
	(1.06)	(.19)	(1.46)	(.19)	(1.15)	(.19)
K	.43	-.04	.54	-.09	.47	-.17
	(.12)	(.07)	(.16)	(.07)	(.14)	(.09)
Q	.68	.94	1.49	.81	2.18	.73
	(.15)	(.19)	(.34)	(.17)	(.49)	(.16)
N	.32	.94	.71	.81	1.04	.73
	(.07)	(.19)	(.16)	(.17)	(.23)	(.16)
E	.36	.94	.78	.81	1.14	.73
	(.08)	(.19)	(.18)	(.17)	(.26)	(.16)
Py	.87	.95	.93	.49	1.41	.01
	(.20)	(.19)	(.21)	(.12)	(.52)	(.11)
W	1.77	.17	1.82	.40	2.82	.51
	(.45)	(.19)	(.47)	(.17)	(.66)	(.13)
Rw	.87	.95	.93	.49	1.28	.54
	(.20)	(.19)	(.22)	(.12)	(.34)	(.13)
R	1.28	.13	1.84	-.05	2.13	-.14
	(.28)	(.09)	(.39)	(.08)	(.46)	(.08)
RR	.06	.92	.07	.92	.06	.93
	(.01)	(.19)	(.02)	(.19)	(.02)	(.19)
P	1.80	-.28	2.05	.20	2.18	.34
	(.42)	(.20)	(.47)	(.16)	(.50)	(.12)

Note: (1) See (1) and (2) in Table A2.
(2) See (2) of the note in Table A5.

Table A8. Two Period Staggered Contracts (MB)

	No Contract		Wage(2)		Price(2)	
	SD	CR	SD	CR	SD	CR
Y	1.51	1.00	1.80	1.00	2.19	1.00
	(.36)	(.00)	(.43)	(.00)	(.49)	(.00)
C	.62	.71	.37	.53	.49	.07
	(.15)	(.15)	(.10)	(.11)	(.12)	(.14)
X	4.72	.93	6.54	.95	8.56	.95
	(1.10)	(.19)	(1.53)	(.19)	(1.93)	(.19)
K	.43	-.06	.55	-.09	.54	-.29
	(.12)	(.08)	(.16)	(.08)	(.14)	(.09)
Q	.69	.94	1.31	.84	3.20	.84
	(.16)	(.19)	(.29)	(.17)	(.72)	(.17)
N	.33	.94	.63	.84	1.52	.84
	(.08)	(.19)	(.14)	(.17)	(.34)	(.17)
E	.36	.94	.69	.84	1.68	.84
	(.08)	(.19)	(.15)	(.17)	(.38)	(.17)
Py	.88	.95	.93	.68	1.69	-.34
	(.21)	(.19)	(.23)	(.15)	(.37)	(.14)
W	1.63	.20	1.88	.31	2.64	.51
	(.42)	(.22)	(.52)	(.18)	(.60)	(.13)
Rw	.88	.95	.93	.68	1.58	.60
	(.21)	(.19)	(.23)	(.14)	(.38)	(.13)
R	.96	.16	1.11	.14	1.32	.04
	(.21)	(.13)	(.24)	(.07)	(.28)	(.10)
RR	.06	.92	.07	.92	.08	.94
	(.01)	(.19)	(.02)	(.19)	(.02)	(.19)
P	1.65	-.31	1.78	.04	1.83	.23
	(.48)	(.17)	(.45)	(.19)	(.45)	(.14)

Note: (1) See (1) and (2) in Table A2.
(2) See (2) of the note in Table A6.

Table A9 Eight Period Contracts

	No Contract		No Staggering				Staggering			
			Wage(8)		Price(8)		Wage(8)		Price(8)	
	SD	CR	SD	CR	SD	CR	SD	CR	SD	CR
Y	1.31	1.00	5.07	1.00	1.21	1.00	1.79	1.00	.86	1.00
	(.30)	(.00)	(1.18)	(.00)	(.30)	(.00)	(.43)	(.00)	(.22)	(.00)
C	.77	.79	1.61	.84	.35	.47	.93	.80	.52	.76
	(.17)	(.16)	(.37)	(.17)	(.09)	(.11)	(.22)	(.16)	(.12)	(.16)
X	3.61	.89	16.39	.95	4.46	.94	5.14	.91	2.44	.88
	(.85)	(.18)	(3.81)	(.19)	(1.10)	(.19)	(1.26)	(.18)	(.63)	(.18)
K	.64	-.21	2.06	-.62	.63	-.53	.86	-.27	.43	-.23
	(.15)	(.10)	(.48)	(.15)	(.14)	(.15)	(.21)	(.13)	(.11)	(.15)
Q	.50	.82	8.28	.93	3.35	.88	1.83	.78	.56	-.23
	(.12)	(.17)	(1.93)	(.19)	(.84)	(.18)	(.46)	(.17)	(.14)	(.14)
N	.24	.82	3.94	.93	1.59	.88	.87	.78	.27	-.23
	(.06)	(.17)	(.92)	(.19)	(.40)	(.18)	(.40)	(.18)	(.07)	(.14)
E	.26	.98	4.34	.93	1.75	.88	.96	.78	.30	-.23
	(.06)	(.17)	(1.01)	(.19)	(.44)	(.18)	(.24)	(.17)	(.07)	(.14)
Py	.91	.92	3.55	-.80	2.29	-.77	1.11	.26	1.13	.85
	(.21)	(.19)	(.83)	(.17)	(.57)	(.17)	(.27)	(.17)	(.26)	(.17)
W	1.69	.12	1.85	.64	2.66	.70	1.18	.20	1.76	-.02
	(.41)	(.16)	(.43)	(.14)	(.63)	(.16)	(.33)	(.13)	(.42)	(.15)
Rw	.91	.92	3.55	-.80	2.14	.91	1.11	.26	.51	.69
	(.21)	(.19)	(.83)	(.15)	(.53)	(.17)	(.27)	(.17)	(.13)	(.15)
R	1.37	.26	1.09	.40	1.53	.22	1.07	.33	1.17	.17
	(.29)	(.09)	(.24)	(.10)	(.23)	(.12)	(.23)	(.09)	(.25)	(.10)
RR	.06	.88	.24	.93	.06	.91	.08	.89	.04	.88
	(.01)	(.18)	(.06)	(.19)	(.01)	(.19)	(.02)	(.09)	(.01)	(.18)
P	1.82	-.34	1.06	-.15	1.68	-.03	1.59	-.05	1.71	-.22
	(.45)	(.15)	(.25)	(.13)	(.42)	(.20)	(.40)	(.11)	(.41)	(.17)
Py&Q	.65		-.90		-.94		-.32		-.65	
	(.15)		(.19)		(.19)		(.17)		(.16)	

Note: (1) See (1) and (2) of the note in Table A2, and Py&Q is correlation between total hours and productivity.
(2) See (2) in Table A5.
(3) Eight period time-to-build is assumed.
(4) Proportion of contract sector is assumed to be 1/3 in staggering cases.

Table A10. Correlation between Total Hours and Productivity

	NO	W(1)	P(1)	W(2)	P(2)
Only Money (M1)	-.31 (.12)	-.95 (.19)	-.95 (.19)	-.96 (.20)	-.95 (.19)
Only Money (MB)	-.64 (.15)	-.95 (.19)	-.95 (.19)	-.96 (.20)	-.95 (.19)
Only Technology	.91 (.19)	.42 (.09)	-.84 (.17)	.29 (.07)	-.93 (.19)
Both Shock (M1)	.90 (.18)	-.64 (.15)	-.86 (.18)	-.79 (.17)	-.93 (.19)
Both Shock (MB)	.87 (.17)	-.47 (.13)	-.87 (.18)	-.72 (.17)	-.93 (.19)
Staggering (M1)				-.03 (.09)	-.61 (.14)
Staggering (MB)				.26 (.10)	-.74 (.16)

Note: W(t) and P(t), t=1, 2, are t-period wage and price contract respectively and NO is the case without contracts.