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A Business Cycle Model With Nominal Wage Contracts and Government

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ABSTRACT

We incorporate nominal wage contracts and government into a quantitative general equilibrium framework. Thus, our model includes three types of shocks: a fiscal shock, a monetary shock, and a technology shock. We show that it is possible in this type of environment to generate a low correlation between hours worked and the return to working, a moderately negative correlation between output and aggregate prices and a moderately positive correlation between the real wage rate and output. In sharp contrast with RBC models with indivisible labor, wage contracts magnify mainly the effect of monetary shocks on the volatility of hours worked. An attractive feature of the contracting model is that it avoids a trade-off that RBC models have to face in their predictive capacity when additional features are incorporated to them.

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1. Introduction

The real business cycle (RBC) paradigm has achieved a great deal of success mimicking some key features of the U.S. data using a neoclassical growth model with only one shock, namely a technology shock. Over the years, the paradigm has been extended in many directions, most of the time motivated by an apparent failure of existing models. For example, a considerable amount of work has been done to make RBC models consistent with labor market phenomena. Following the path-breaking paper by Kydland and Prescott (1982), one item that came high on the research agenda was to explain the fact that the volatility of hours worked is not only large relative to the volatility of productivity but, also, that it is almost equal to the volatility of output. Kydland and Prescott (1982) have shown that a model where all workers are constrained to work the same number of hours in equilibrium and where the total number employed does not vary is inconsistent with these facts.

Hansen (1985) has shown that the addition of labor indivisibilities (see Rogerson [1988]) to a stochastic growth model could raise the volatility of hours worked significantly. In Hansen's model, the number of persons employed rather than the hours worked per employee varies. However, in this environment, it is possible to increase the volatility of hours worked only at the cost of a poorer match for the volatility of productivity and of a significant deterioration of the match with the observed ratio of the volatility of hours relative to productivity.

Later, Cho and Cooley (1989) and Kydland and Prescott (1991) have developed models in which hours per worker and the number of workers employed are variable. The ratio of the volatility of hours relative to productivity predicted by the model economy is closer to the observed value in the model of

Kydland and Prescott (1991) than in Hansen's model with indivisible labor.[1] However, this improvement is obtained at the cost of a reduction of the volatility of hours predicted by the model relative to the actual one. Thus, it seems that the incorporation of additional features to RBC models leads to an improvement of the match of the model economy along certain dimensions but only at the cost of a poorer match along other dimensions.

More recently, another fact pertaining to the labor market has raised a significant amount of attention. It concerns the correlation between aggregate hours worked and the return to working found in the U.S. data which is either close to zero or moderately negative (see Hansen and Wright [1992]). RBC models driven by technology shocks predict that this correlation should be strongly positive.

Christiano and Eichenbaum (1992) have tried to solve this hours worked-productivity puzzle by adding a second disturbance to the model, namely, a government spending shock.[2] They use *household data* and *establishment data*. With the first set of data, they find that a RBC model that incorporates government does not explain the low correlation between hours and productivity. With the second data set, they are unable to reject the hypothesis that a RBC model with indivisible labor and government is consistent with both the observed correlation between hours and productivity and the observed ratio of the volatility of hours relative to productivity. However, the incorporation of stochastic government spending also gives rise

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1 This follows from the fact that hours worked are less volatile and productivity is more volatile than in Hansen's model.

2 Baxter and King (1990), Aiyagari, Christiano and Eichenbaum (1990), McGrattan (1991) and Roche (1991), among others, have also included fiscal policy into business cycle models.

to a trade-off in the model economy, deteriorating the match of the model for the volatility of output, the volatility of productivity and the ratio of the volatility of productivity relative to output.

Another way to generate a low correlation between hours worked and productivity is to introduce household production as in Benhabib, Rogerson and Wright (1991), enabling individuals to substitute between market and home production. They show that, in principle, the home production model can yield a low correlation between hours and productivity. However, the transition from the model that omits home production to the one that includes it, also gives rise to a trade-off, improving the match of the model for the ratio of the volatility of hours worked relative to output at the cost of a deterioration of the match for the ratio of the volatility of productivity relative to output.

In the present paper, we adopt a different approach. We incorporate a nominal rigidity in the form of nominal wage contracts into a dynamic general equilibrium framework together with government. This allows us to model three types of shocks: a government spending (fiscal) shock, a technology shock and a monetary shock. Our main goal is to find whether the wage-contracts model with government can replicate the important labor market phenomena that we have just described. We are also interested to learn if the contracting model avoids the type of trade-off that RBC models face when additional features are incorporated to them.

A few other researchers have also tried to assess the importance of monetary shocks over the business cycle. Kydland (1989) introduces a possible role for money through imperfect information as in Lucas' (1972) model or through a trade-off between real money and leisure. However, he finds that monetary shocks do not have a significant impact over the business cycle. Cooley and Hansen (1989) introduce money through a cash-in-advance constraint and find that anticipated monetary shocks only have small real effects. In studying the role of nominal rigidities in a business cycle model, we follow Cho (1990), Cho and Cooley (1990), King (1990) and Lucas (1989).

Traditionally, demand shock models have problems explaining two other important facts. First, that real wages are mildly procyclical.[3] This contradicts demand shock models that produce countercyclical real wages. Second, contrary to a common belief, postwar data imply a countercyclical movement in aggregate prices.[4] Equilibrium models based on monetary misperceptions (Lucas [1972] and Barro [1976]) and nonmarket clearing models (Gray [1976] and Fischer [1977]), have emphasized the procyclical behavior of prices. We examine if the combination of demand and technology shocks explains these two facts.

Our main results can be summarized as follows. If only spot markets exist, the model fails to reproduce some important features of the data. This leads us to incorporate different structures of wage contracts. The first structure is one in which the only departure from the market-clearing model is the presence of nominal wages determined by contracts settled one period in advance. Our results indicate that, even if this represents only a slight modification made to the basic RBC model, the predictions of the model improve dramatically. In particular, one-period nominal wage contracts contribute more to increase the volatility of hours worked than labor indivisibility. In sharp contrast with Hansen-Rogerson indivisible labor, wage contracts mainly amplify the effect of monetary shocks on hours worked. The model's

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3 See Geary and Kennan (1983), Bils (1985) and Barsky and Solon (1988).

4 This fact has been documented recently by Kydland (1989), Kydland and Prescott (1990), Crucini (1991), Cooley and Ohanian (1991) and Backus and Kehoe (1992).

predictions are consistent with almost all aspects of the data, including the correlations between variables. This is true for combination of monetary and technology shocks as well as with the three shocks combined.

Next, we study the implications of increasing the length of contracts. We examine the case where all nominal wages are determined by contracts settled four periods in advance. With this structure of contracts, we show that the best results are those obtained when fiscal and technology shocks are the main forces driving the business cycle. Any other combination of shocks yields a volatility of output, of hours worked and of productivity that are larger than those found in the data. However, the results are not as persuasive as with one-period contracts.

Finally, we modify the structure of contracts into one where four-period wage contracts are staggered over time as suggested by Taylor (1980) and where only a fraction of nominal wages are determined in the contracting sector with the remaining fraction settled in a spot market. We show that this model yields accurate predictions concerning the volatility of aggregates and the correlations between variables with a combination of monetary and technology shocks or with the three shocks combined.

Overall, although our results indicate that nominal wage contracts could be an important element in the explanation of business cycles, they also show the importance of technology shocks. Finally, they suggest that the contracting model has the potential to avoid the kinds of trade-off facing the predictive capacity of RBC models.

The paper is organized as follows. In section 2, we describe the model with wage contracts and government. In section 3, we explain how the model is calibrated. Section 4 presents and explains the simulation results. Section 5 contains concluding remarks.

2. The Economy

We assume a continuum of identical agents or households. Each agent is endowed with one unit of time per period, initial capital stock k_0 and initial money holdings m_0. Throughout, lowercase letters denote individual variables and capital letters denote their aggregate per-capita counterparts.

Each agent maximizes the following lifetime utility:

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

where c_t is consumption, G_t is government expenditure, ℓ_t is leisure and β is the discount factor. We assume the following temporal utility function:

$$u(c_t, G_t, \ell_t) = \frac{1}{1-\sigma} \cdot \left\{ \left(c_t + \alpha_1 G_t\right)^{\gamma} \ell_t^{1-\gamma} \right\}^{1-\sigma}, \tag{2.2}$$

where $0 \le \alpha_1 \le 1$. Note that if $\alpha_1 = 1$, government and private consumptions are perfect substitutes.[5]

Agents maximize (2.1) subject to the following sequence of budget constraints:

$$(1+\tau_t^c) \cdot c_t + x_t + \frac{m_t}{P_t} \le (1-\tau_t^n) w_t n_t + (1-\tau_t^k) r_t k_t + \tau_t^k \delta k_t + \frac{m_{t-1}}{P_t} + \frac{(\mu_t - 1) M_{t-1}}{P_t} + Tr_t. \tag{2.3}$$

The variables on the left-hand side of (2.3) are the household expenditures and those on the right-hand side are the available funds. The expenditures

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[5] See Barro (1981) and Roche (1991) for this specification of preferences. Aschauer (1985) estimates α_1 using U.S. data.

include purchases of consumption goods (τ_t^c denotes the consumption tax), investment (x_t) and money to be carried into the next period. The available funds for this purchase stem from after-tax labor income (τ_t^n is the labor income tax, w_t is the real wage rate, and $n_t=1-\ell_t$) and after-tax capital income (τ_t^k is the capital income tax, r_t is the real rental rate of capital, and k_t is the capital stock owned by the household); the third term on the right-hand side is the depreciation allowance built into the tax code (δ is the capital depreciation rate). The last terms are the currency carried over from the previous period (m_t is household's money holdings in period t which is carried into the next period and P_t is the price level), a lump sum cash transfer from the government (μ_t is the gross growth rate of money and M_t is the aggregate per capita money stock), and a government transfer Tr_t.

In addition, the household faces a cash-in-advance constraint. Asset trading is permitted only at the beginning of the period, before the trading in the goods market. Households obtain at that time the currency needed to buy consumption goods. At the beginning of period t, the household has money holdings equal to m_{t-1} and the government transfers newly created money to the private agent. Hence, the cash-in-advance constraint can be written as follows,

$$(2.4) \qquad (1+\tau_t^c)P_t c_t \le m_{t-1} + (\mu_t - 1)M_{t-1}.$$

This constraint will be binding in the simulation section. In fact, (2.4) will hold with equality under reasonable conditions.[6]

The capital stock follows the usual law of motion,

[6] See Cooley and Hansen (1991).

(2.5) $$K_{t+1} = (1-\delta)K_t + X_t, \quad 0<\delta<1.$$

The per-capita capital stock follows a similar law of motion.

Output, Y_t, is produced by the firm with the following Cobb-Douglas technology:

(2.6) $$Y_t = A_t K_t^{\theta_1} N_t^{1-\theta_1} (K_t^G)^{\theta_2}, \quad 0<\theta_1<1,$$

where θ_1 is the share of capital, K_t^G is the stock of publicly provided capital, and A_t is the productivity shock.[7] The technology shock follows a AR(1) process.[8]

(2.7) $$\ell n(A_{t+1}) = \rho_1 \ell n(A_t) + \varepsilon_{1,t+1}, \quad \text{where } 0\leq \rho_1 \leq 1 \text{ and } \varepsilon_{1,t} \sim \text{i.i.d. } N(0,\sigma_1^2).$$

In the absence of nominal rigidities, the profit maximization problem for the firm yields the following wage and rental rate functions:

(2.8) $$w(A_t,K_t,N_t,K_t^G) = (1-\theta_1)A_t\left(K_t/N_t\right)^{\theta_1}\left(K_t^G\right)^{\theta_2},$$

(2.9) $$r(A_t,K_t,N_t,K_t^G) = \theta_1 A_t\left(K_t/N_t\right)^{1-\theta_1}\left(K_t^G\right)^{\theta_2}.$$

If there is a nominal wage contract, the wage function should be determined differently from (2.8).

Government revenue, used to finance a sequence of government

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7 See Baxter and King (1990) for the role of the publicly provided capital.

8 We abstract from growth.

expenditures, is generated by a AR(1) process,

$$(2.10)\quad G_{t+1} = \rho_2 \cdot G_t + \varepsilon_{2,t+1}, \quad \text{where } 0 \le \rho_2 \le 1 \text{ and } \varepsilon_{2,t} \sim \text{i.i.d. } N((1-\rho_2)G,\ \sigma_2^2),$$

and G is mean (or steady state) government expenditures. The government's monetary policy rule is:

$$(2.11)\qquad M_{t+1} = \mu_{t+1} \cdot M_t,$$

The gross growth rate of money μ_t follows the following AR(1) process:

$$(2.12)\qquad \ell n(\mu_{t+1}) = \rho_3 \ell n(\mu_t) + \varepsilon_{3,t+1}, \quad \text{where } 0 \le \rho_3 \le 1$$
$$\text{and } \varepsilon_{3,t} \sim \text{i.i.d. } N((1-\rho_3)\cdot \ell n(\mu),\ \sigma_3^2),$$

where μ is the steady state growth rate of money. The government's fiscal policy includes the sequence of government expenditures and a sequence of factor incomes and consumption taxes. This policy is feasible in the sense that the present value of government expenditures equals the present value of the stream of revenues. The government balances the budget in each period by adjusting a lump sum transfer (or tax) Tr_t and thus, the following equality holds in each period:

$$(2.13)\qquad G_t = \tau_t^n w_t N_t + \tau_t^k (r_t - \delta) K_t + \tau_t^c C_t + Tr_t.$$

The initial transfer payment Tr_0 is assumed to be equal to zero. Also, a fraction of government expenditures is devoted to the accumulation of public capital, (2.14) $$I_t^G = \alpha_2 G_t,$$

where α_2 is between 0 and 1. In other words, the fraction α_1 of G_t is directly transfered to the private sector as consumption goods, α_2 of G_t is invested in public capital, and the remaining $(1-\alpha_1-\alpha_2)$ fraction of G_t is consumed by the government. The law of motion for the public capital stock can be written as:

(2.15) $$K_{t+1}^G = (1-\delta)K_t^G + I_t^G.$$

The final feature of the model is the nominal wage contract. We follow the nominal contracts developed by Gray (1976) and Fischer (1977). Under these arrangements the contract wage rate that prevails in period t is determined in period t-j and the workers are assumed to cede the firm the right to determine the aggregate hours in period t, that is, they work as many hours as demanded by the firm. Recently, there have been a few attempts to incorporate nominal contracts in a dynamic general equilibrium framework (Cho [1990], Cho and Cooley [1990], King [1990] and Lucas [1989]). Cho (1990) and King (1990) define the contract wage rate as equal to the anticipated value of the marginal product of labor. In other words, they assume that the contract wage is set by the demand side of the labor market. Here, we adopt a different strategy. First, we assume the following additional constraint in the household's problem:

(2.16) $$n_t = N_t,$$

which simply means that the household takes the total hours as given in solving the problem. The contract wage rate is the one for which the anticipated marginal disutility of working one more hour is equal to the anticipated benefit of doing so. In other words, we assume that the contract wage is determined by the supply side of the labor market. The contract wage for which the marginal value of the quantity constraint (2.16) is set at zero in the steady state is the following:[9]

$$(2.17)\qquad \ell n(W^c_t) = E\left\{\ell n\left(\frac{1-\gamma}{\beta\gamma}\right) + \ell n\left(\frac{1+\tau^c_t}{1+\tau^n_t}\right) + \ell n(\mu_t) + \ell n(P_t) + \ell n(C_t+\alpha_1 G_t) - \ell n(1-N_t)\,\middle|\,\Omega_{t-j}\right\}$$

where Ω_{t-j} is the information available in period t-j.[10,11]

3. Calibration

Many of the parameter values are borrowed from previous studies by Kydland and Prescott (1982), Hansen (1985) and Prescott (1986), Baxter and King (1990) and Cooley and Hansen (1991) among others. β is assumed to be .99, which means that the steady state interest rate is four percent per annum. As in Baxter and King (1990), we set the depreciation rate equal to .025 per quarter for both private and public capital. The value of γ is

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[9] Set up the Lagrangian function for the household's optimization problem and take the derivative with respect to N_t. Setting the derivatives at zero and using the aggregate consistent conditions ($c_t = C_t$ etc.), we can have (2.17). This equation can also be viewed as the missing first order condition due to the quantity constraint imposed by nominal contracts.

[10] Cho (1990) explains in details how to calculate the contract wage.

[11] Moreover, it is possible to show that, under certain assumptions, the contract wage rates defined in Cho (1990) and King (1990) imply exactly the same decision rules as in (2.17).

assumed to be .40. This implies the steady state hours of work to be one third of the endowment of time. The value of the intertemporal substitution parameter σ is assumed to be equal to two. This value is used by Backus, Kehoe and Kydland (1988), Stockman and Tezar (1990) and Roche (1991). The values for α_1 and α_2 are set to be .20. The value for α_1 is borrowed from Aschauer (1985) and that for α_2 is chosen to keep steady state public investment at about five percent of GNP. The share parameter of private capital θ_1 is assumed to be .36, which is widely used in the literature. The share parameter of public capital θ_2 is set at .05 and this value was used as the benchmark by Baxter and King (1990). Tax rates are assumed to be fixed over time. Cooley and Hansen (1991) justify values for τ^n and τ^k of .23 and .50, respectively. The consumption (sales) tax is equal to .07. The growth rate of money is fixed at three percent per quarter.

The AR(1) parameter in the technology shock process is set to be .95 and the standard deviation of the innovation to the process to be .009, which lies on the upper bound of the estimates in Prescott (1986). The processes for money growth and government expenditures are pinned down by looking at postwar U.S. data. We find that ρ_2 = .94, ρ_3 = .48, σ_2 = .00640, and σ_3 = .00985. The money growth process is the same as in Cooley and Hansen (1989), and the size of the fiscal shock is comparable to the one used by Christiano and Eichenbaum (1992).

The solution method that we adopt is the one used by Cho (1990) and Cho and Cooley (1990), which is a variation of the method suggested by Kydland (1989) and applied by Cooley and Hansen (1989). It involves computing a linear quadratic approximation to the household's problem and solving by iterating on Bellman equation.[12] A detailed description of the solution

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[12] Before approximation, we need to tranform all nominal variables by

process is available in Cho (1990). For each reported case, we simulate the model economy 25 times over 115 periods.

4. Simulation results

4.1 Business cycle statistics

We begin this section by documenting the relevant business cycle facts we shall be comparing with the predictions of the different versions of our model. We borrow these statistics from Hansen and Wright (1992) who consider measures of hours worked from four different sources. Since the main focus of the simulation exercize is to analyze the implications of our model for the labor market, the data reported by Hansen and Wright on hours worked are extremely helpful.

Table 1a contains statistics on the volatility of some aggregates and Table 1b, the correlations between variables. Each series has been detrended using the Hodrick-Prescott filter. We observe that consumption is less than half as volatile as output and that investment is more than three times as volatile as real GNP. RBC models have been successful in replicating these facts.

The data on hours worked used to calculate the ratio of the volatility of hours worked to the volatility of output σ_N/σ_Y, the ratio of the volatility of productivity to the volatility of output σ_{Py}/σ_Y and the ratio of the volatility of hours to the volatility of productivity σ_N/σ_{Py}, come from four different sources. The ratios that are reported on the line labelled HSAI in Table 1a have been calculated using the total number of hours worked as

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dividing them by the monetary growth factor $\exp(\mu\cdot t)$.

recorded in the household survey for all industries; on the line marked ESNAI, we find the ratios obtained with total hours worked as recorded in the establishment data survey covering only nonagricultural industries; the ratios reported on the line labelled HSNAI have been calculated with total hours worked recorded in the household survey but, this time, only for nonagricutural industries; the ratios appearing on the line EU are based on the measure of hours worked in "efficiency units" that Hansen (1991) constructed by disaggregating the total number of hours worked in nonagricultural industries recorded in the household survey into age and sex groups and by weighting the hours of each group by its relative hourly earnings.

With either measure, total hours worked has a cyclical variation which is almost as large as that of real GNP in percentage terms. The value of the ratio σ_N/σ_Y ranges from 0.82 to 1.01, depending on the hours series. Hours worked are more volatile than productivity with the value of the ratio σ_N/σ_{Py} ranging from 1.37 to 1.95, depending on the hours series.

Looking at the correlations between variables listed in Table 1b, we observe that the correlations between consumption and output, investment and output and hours worked and output are all strongly positive. The correlations between output and productivity and between real wages and output are moderately positive. Output and aggregate prices are negatively correlated. Finally, the value of the correlation between hours worked and productivity ranges from 0.10 to -0.35, depending on the hours series.

4.2 Simulation results with spot markets

In Table 2, we report the results of a simulation of the standard version of our model, that is, we begin by considering the case where all nominal wages are set in a spot market. It is a common practice to use the standard model as a benchmark and then, to study the implications of incorporating additional features.

Table 2a contains the results on the volatility of aggregates. The most notable result in Table 2a is that demand shocks (fiscal and monetary) contribute almost nothing to output volatility, to the volatility of hours worked and to the volatility of average productivity and contribute only 49% to the volatility of investment when they are combined. Furthermore, a look at the correlations between variables in Table 2b indicates that the fiscal shock yields a strong negative correlation between consumption and output while this correlation is positive in the data and a strong positive correlation between output and aggregate prices while it is actually negative. Contrary to the facts, the monetary and fiscal shocks both give rise to correlations between investment and output, productivity and output, hours worked and productivity and output and real wages that are all strongly negative.

With the technology shock only, the volatility of output predicted by the model economy increases to 1.38 compared to 1.74 in the data. Moreover, the model correctly predicts that consumption is less volatile than output and that investment varies considerably more than real GNP. Unfortunately, the volatility of hours worked predicted by the model is too low, a result that is consistent with Hansen's (1985) finding with divisible labor. The volatility of productivity is somewhat larger here than in Hansen's model. Turning to the correlations generated by the technology shock only, we observe that the correlations between consumption and output and between productivity and output implied by the model economy are positive and significantly higher than those found in the data, and that the correlations between hours worked and productivity and between output and real wages, which are respectively equal to 0.96 and 0.99 according to the model, are too high compared to the correlations found in the data. Finally, with technology shocks only, the correlation between output and aggregate prices generated by the model is -0.99 while it is -0.55 in reality.

Combining the technology shock with demand shocks increases the volatility of output somewhat. For example, with the three shocks combined the volatility of output predicted by the model increases to 1.41. However, the model fails miserably to reproduce the ratios of the volatility of hours worked relative to the volatility of output and of the volatility of hours relative to the volatility of productivity regardless of the combination of shocks. As for the correlations, combining the technology shock with the two demand shocks reduces the correlation between hours and productivity but, at 0.68, it remains too high. The correlations between output and productivity and between output and real wages implied by the model economy are also much too high.

4.3 Simulation results with nominal wage contracts

i) One-period nominal wage contracts

In the present section, we relax the assumption that nominal wages are determined in a spot market. We assume instead that they are set one period in advance by contracts summarized in equation (2.17). We begin with one-period contracts because this contracting structure can be viewed as representing only a small departure from the market-clearing model. Thus, our simulation results should indicate whether it is necessary to modify the standard model considerably in order to improve the model's predictions. The answer to this question tuns out to be negative.

Table 3a shows the values of the volatility of aggregates predicted by the contracting model. A notable feature of wage contracts is that they increase the volatility of output in the face of each shock. The most important effect takes place in the case of the monetary shock. The volatility of output generated by the monetary shock is now 10 times larger than with spot markets. Nominal contracts also play a significant role in magnifying the effects of government expenditure shocks on the volatility of output. The most accurate predictions are obtained with the combination of monetary and technological shocks and with the three shocks combined. With monetary and technology shocks, the volatility of output predicted by the model is 1.66 and it is 1.78 with the three shocks; the actual value is 1.74.

Another striking effect of wage contracts is that they increase the volatility of hours worked under each shock or combination of shocks. But, in sharp contrast with RBC models, it is with the monetary shock that the magnifying effect on hours worked is the most important. With monetary shocks only, the volatility of hours worked increases from 0.15 with spot markets to 1.45 with one-period wage contracts while the actual volatility of hours lies between 1.42 and 1.75 depending on the hours series. With technology shocks alone, the volatility of hours worked is only 0.47 (it was 0.38 in the market-clearing model). With monetary and fiscal shocks combined, the volatility of hours becomes equal to 1.61; with the combination of monetary and technology shocks and with the three shocks combined, it is respectively equal to 1.54 and 1.69. However, it is when the monetary and technology shocks are combined or with the combination of three shocks that the ratio of the volatility of hours worked relative to the volatility of output predicted by the contracting model falls in the range of actual values (0.82 to 1.01).

These results concerning the volatility of hours worked show that nominal wage rigidity may be viewed as a complement (or perhaps as an alternative) to the concept of labor indivisibility introduced in RBC models by Hansen (1985) and Rogerson (1988). However, nominal wage contracts are a very different dynamic propagation mechanism than indivisible labor, increasing mostly the effect of monetary shocks on hours worked. Another important difference is that wage contracts also magnify the volatility of average productivity in the face of each shock. In Hansen's (1985) model, the incorporation of indivisible labor lowers the volatility of average productivity.[13]

Wage contracts also contribute to lower the ratio of consumption volatility relative to output volatility in the face of demand shocks. For example, in the market-clearing model, this ratio was equal to 4.78 with monetary shocks alone and to 3.19 with fiscal and monetary shocks combined; it becomes equal to 0.41 and 0.60, respectively, with the nominal wage rigidity. Overall, the results concerning the volatility of aggregates obtained with one-period wage contracts could be viewed as very good with the combination of monetary and technology shocks or with the three shocks combined. They also indicate that technology shocks have to be taken into account to obtain accurate predictions.

The incorporation of wage contracts also affects significantly the correlations between variables. This is shown in Table 3b. Demand shocks now yield a positive correlation between output and investment. However, with demand shocks only, the contracting model has many counterfactual implications. The most notable are that they give rise, either taken alone or combined, to correlations between hours worked and productivity, output and real wages and productivity and output that are strongly negative.

On the other hand, when the only shock is the technology shock, the correlations between hours worked and productivity, output and real wages and productivity and output are all counterfactually strongly positive while the

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13 This seems to be also the case in RBC models with nonseparable lesisure (Kydland and Prescott [1982]), with government spending (Christiano and Eichenbaum [1992]) and with home production (Benhabib, Rogerson and Wright [1991]).

correlation between output and aggregate prices implied by the model is too negative.

Again, it is when the technology shock is combined with the monetary shock or with the two demand shocks that the contracting model yields the most accurate results. First, let us consider the correlation between aggregate prices and output. Since the effect of monetary shocks on this correlation is moderately negative while the effect of fiscal shocks is strongly positive, the combination of technology shocks with monetary shocks or with the two demand shocks yields quite accurate predictions (-.36 and -.42 respectively, compared to the actual correlation of -.55). This shows that when technological shocks are assumed, a model with nominal wage rigidity is not necessarily inconsistent with the evidence of a countercyclical behavior in output price.

The correlation between aggregate hours and productivity is significantly reduced with a combination of technology and demand shocks. It is -.24 with technology and monetary shocks and -.26 with the three shocks combined. In both cases, it falls within the range of actual values (from -.35 to .10) depending on the hours series. These correlations implied by the contracting model are much lower than those obtained with the market-clearing model. The model can also generate a correlation between the real wage rate and output that is close to the actual correlation when the monetary and technology shocks are combined or with the combination of three shocks. With monetary and technology shocks, it is equal to .43 and with all shocks combined, it falls to .39. The actual correlation between output and real wages is .35. With the same combinations of shocks, the correlation between productivity and output implied by the contracting model also falls within the range of actual values.

Overall, these results indicate that modifying the standard RBC model only slightly introducing one-period wage contracts is enough to improve the predictions of the model dramatically.

ii) Four-period nominal wage contracts

Next, we examine the implications of increasing the length of contracts. The case which we consider now is one where all nominal wages in the model economy are set four periods in advance by wage contracts. As Table 4a shows, the main effect of a longer duration for contracts is to increase considerably the volatility of output and the volatility of hours worked in the face of demand shocks. Combining fiscal and monetary shocks yields a volatility of output and a volatility of hours worked that are implausibly high; they are respectively equal to 2.57 and 4.06. Any combination of shocks with the monetary shock generates too much volatility in output and hours worked. Increasing the length of contracts also has an unfavorable effect on the ratio of the volatility of hours relative to the volatility of productivity. The fiscal and the monetary shock each generates a ratio that is too high. While in the case of one-period contracts, combining the technology shock with the monetary shock or with the two demand shocks generate predictions that fall in the range of actual values, the same combinations of shocks yield ratios that are equal to 2.28 and 2.24 respectively, outside the range of actual values (1.37 to 1.95).

Recall that with one-period wage contracts, the correlations between variables implied by the contracting model were broadly consistent with the facts in the presence of a combination of monetary and technology shocks or with the three shocks. It is not the case with four-period wage contracts. A look at Table 4b suggests that the correlation between output and aggregate prices is almost unaffected by the increase in the length of contracts. However, it has an important effect on other correlations. The correlations between real wages and output and productivity and output now become negative when the technological is combined either with the monetary shock or with the two demand shocks. The correlation between hours worked and productivity, although it remains negative under these two combinations of shocks, is too negative. Tables 4a and 4b suggest that, overall, the most accurate predictions are those obtained with the combination of fiscal and technological shocks. However, they are not as persuasive as those obtained with a combination of monetary and technology shocks and with the three shocks combined with one-period wage contracts.

iii) Four-period staggered wage contracts

Since it is common sense to believe that not all nominal wages in the economy are determined by contracts, we consider a different structure. First, we assume that only a fraction of nominal wage settlements are set by four-period contracts in each period with the remaining fraction determined in a spot market and, second, that contracts are staggered over time as in the model of Taylor (1980). More specifically, one fourth of wage settlements are renewed each period.[14] We would have liked to rely on the data to choose the fraction of nominal wages determined in the contracting sector. Unfortunately, this information was not available. Instead, we have decided to infer the fraction of nominal wages determined by contracts required to replicate business cycle phenomena.

In Tables 5a and 5b, we report the results of a numerical simulation of the model with 35% of wage settlements taking place in the contracting sector four periods in advance and one fourth of the contracting sector renewing their contract each period. Table 5a indicates that the most accurate

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[14] Taylor (1980) makes a similar assumption.

predictions are obtained with a combination of monetary and technology shocks or with the three shocks combined. We also note with interest that the results are in general similar to those obtained with all nominal wages set one period in advance.

Again, our results suggest that staggered contracts may be useful to understand business cycle phenomena and that technology shocks must be assumed. With demand shocks only, the model generates too little volatility of output and productivity and too much volatility of hours worked relative to output and to productivity.

Table 5b contains the results of the simulation for the correlations between variables. This time, the combination of monetary and technology shocks seems to produce the most accurate results. When the monetary and technology shocks are combined, the correlation between output and aggregate prices predicted by the model is -.28 compared to -.55 for the actual correlation. With all three shocks combined it is -.17. With non staggered four-period contracts, the combination of the technology shock with the monetary shock or with the two demand shocks produced a negative correlation between output and real wages. With staggered contracts, it becomes .36 with the monetary and technology shocks combined and .24 with the combination of three shocks. With the combination of monetary and technology shocks, the correlations between hours worked and productivity and productivity and output implied by the staggered contracts model economy fall in the range of possible actual values with -.29 and .36 respectively. The results are also encouraging with the three shocks combined.

4.4 *A comparison of the behavior of real and contracting economies*

Are there any fundamental differences in the behavior of real and contracting economies? To answer this question, we present a table that gives an idea of how these two types of economies behave when additional features are added to them. We take some key models in the RBC literature, namely, Hansen's (1985) model with divisible and indivisible labor and the model of Christiano and Eichenbaum (1992) with divisible and indivisible labor, with and without government, and we compare their behavior with that of the contracting model.

We have selected some statistics that have been the object of considerable attention in past research and, for each of them, we have computed the ratios of the values predicted in these models relative to their actual values. For example, assuming that Z is some statistic, Z^*/Z is the ratio of Z^*, the value of Z predicted by a particular model, divided by the actual value of Z. The closer the value of this ratio is to one, the more accurate is the prediction. The predictions generated by Hansen's model and by the contracting model are compared with the business cycle statistics reported in Hansen's study covering the period 1955:3 to 1984:1. In Christiano and Eichenbaum, the data cover the period 1955:4 to 1983:4.[15] These ratios are reported in Table 6.

In Hansen's model, the incorporation of indivisible labor into a RBC model in which the only shock is a technology shock improves the predictive capacity of the model with respect to the volatility of hours worked and to the ratio of the volatility of hours worked relative to the volatility of output. However, with the transition from divisible to indivisible labor, the predictions for other statistics become worse. It is the case for the volatility of productivity, the ratio of the volatility of productivity to the

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15 We are not comparing the predictions from the model of Christiano and Eichenbaum with Hansen's data or with more recent data because their model's calibration is based on an estimation over the sample 1955:4 to 1983:4.

volatility of output and for the ratio of the volatility of hours worked relative to the volatility of productivity. In the last two cases, the deterioration of the predictive capacity of the model is particularly important.

In general, the incorporation of government seems to improve significantly the predictive capacity of RBC models. In the study by Christiano and Eichenbaum (1992), the transition from a model with divisible labor and without government to a model with indivisible labor and government, improves dramatically the accuracy of the predictions concerning the volatility of hours worked and the ratio of the volatility of hours relative to the volatility of productivity. However, it reduces the predictive capacity of the model for the volatility of output, the volatility of productivity and most importantly, the ratio of the volatility of productivity relative to the volatility of output. In the last case, the ratio of the prediction to the actual number decreases by 28.9%. Thus, adding government to a RBC model gives rise to a trade-off since the model improves in replicating some key statistics but only at the cost of a poorer match for other statistics.

The last three lines in the table contain the ratios of the predictions relative to the actual numbers arising from the version of our model with market-clearing (MCM), with one-period wage contracts (1WCM) and with four-period staggered wage contracts (4SCM) with the combination of fiscal, monetary and technology shocks. One striking feature of the results is that the transition from the MCM to the 1WCM or to the 4SCM improves the predictions for all statistics (except for the ratio of the volatility of productivity relative to the volatility of output which is close to one in the three models). With the 1WCM and the 4SCM, the ratio of the value predicted by the contracting model relative to the actual number is close to one for almost each statistic. While in RBC models the predictions concerning hours worked and the ratio of the volatility of hours to the volatility of productivity can be improved only at the cost of a significant deterioration of the match for the volatility of output and for the ratio of the volatility of productivity to the volatility of output, contracting models can possibly generate predictions concerning all these statistics that are simultaneously close to their actual values. This potential absence of a trade-off in the predictive capacity of the contracting model suggests that wage contracts may be very useful in understanding business cycle phenomena.

5. Conclusion

We have developed a business cycle model with nominal wage contracts and government. This allowed us to incorporate the effects of three shocks over the business cycle: a government spending (fiscal) shock, a monetary shock and a technological shock. We think the main conclusion that can be drawn from our results is that, compared to pure RBC models, sticky wage models have the potential ability to yield accurate predictions concerning the statistical properties of most aggregate time series without giving rise to a trade-off in the predictive capacity of the model. In pure RBC models, the incorporation of additional features increases the predictive capacity of the model for some statistics but only at the cost of a poorer match for others. This trade-off seems to be absent in contracting models.

The incorporation of nominal wage contracts in a dynamic general equilibrium framework has many attractive features. First, unlike pure RBC models in the literature, it can generate a negative correlation between hours worked and productivity. Second, unlike pure demand shock models, it can yield a negative correlation between output and aggregate prices as well as a positive correlation between real wages and output.

It would be interesting in future research to consider the effects of other contracting schemes on the business cycle. Different bargaining structures could be incorporated. One promising approach would be to develop a business cycle model in which employment is determined unilaterally by the firm, as in the present model, with the wage being either the outcome of bargaining or determined by the union. Another, would be to work out a model where there is efficient bargaining over wages and employment. These refinements are beyond the scope of this paper. We think, however, that our results are promising enough to make this line of research worth pursuing further.

REFERENCES

Aiyagari, S.R., L.J. Christiano and M. Eichenbaum (1990), "The Output, Employment, and Interest Rate Effects of Government Consumption," Institute for Empirical Macroeconomics Working Paper No. 25.

Aschauer, D.A. (1985), "Fiscal Policy and Aggregate Demand," *American Economic Review* 75, 117-127.

Backus, D.K. and P.J. Kehoe, "International Evidence on the Historical Properties of Business Cycles," *American Economic Review* 82, 864-888.

Backus, D.K., P.J. Kehoe and F.E. Kydland (1989), "International Borrowing and World Business Cycles," Federal Reserve Bank of Minneapolis Working Paper No. 426R.

Barro, R.J. (1976), "Rational Expectations and the Role of Monetary Policy", *Journal of Monetary Economics* 2, 1-32.

Barro, R.J (1981), "Output Effects of Government Purchase," *Journal of Political Economy* 89, 1086-1121.

Barsky, R. and G. Solon (1988), "Real Wages over the Business Cycle," manuscript, University of Michigan.

Baxter, M. and R.G. King (1990), "Fiscal Policy in General Equilibrium," University of Rochester Working Paper No. 244.

Benhabib, J., Rogerson, R. and R. Wright (1991), "Homework in Macroeconomics: Household Production and Aggregate Fluctuations," *Journal of Political Economy* 99, 1166-1187.

Bils, M. (1985), "Real Wages over the Business Cycle: Evidence from Panel Data," *Journal of Political Economy* 93, 666-689.

Cho, J.-O. (1990), "Money, Nominal Contracts and the Business Cycle: I. One Period contract Case," Queen's University Working Paper No. 780.

Cho, J.-O. and T.F. Cooley (1989), "Employment and Hours Over the Business Cycle", *Journal of Economic Dynamics and Control*, forthcoming.

Cho, J.-O. and T.F. Cooley (1990), "The Business Cycle with Nominal Contracts," University of Rochester Working Paper.

Christiano, L.J. and M. Eichenbaum (1992), "Current Real Business Cycle Theories and Aggregate Labor Market Fluctuations," *American Economic Review* 82, 430-450.

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

Cooley, T.F. and G.D. Hansen (1991), "Tax Distortions in a Neoclassical Monetary Economy," Institue for Empirical Macroeconomics Working Paper No. 38.

Cooley, T.F. and L. Ohanian (1991), "The Cyclical Behavior of Prices," *Journal of Monetary Economics* 28, 25-60.

Crucini, M.J. (1991), "Price Deflation and Real Tariff Rates: The United States, 1903 to 1940," Institute for Empirical Macroeconomics Working Paper No. 42.

Fischer, S. (1977), "Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule", *Journal of Political Economy* 85, 191-205.

Geary, P.T. and J. Kennan (1982), "The Employment-Real Wage Relationship: An International Study," *Journal of Political Economy* 90, 854-871.

Gray, J.A. (1976), "Wage Indexation: A Macroeconomic Approach," *Journal of Monetary Economics* 2, 221-236.

Hansen, G.D. (1985), "Indivisible Labor and the Business Cycle," *Journal of Monetary Economics* 16, 309-327.

Hansen, G.D. (1991), "The Cyclical and Secular Behavior of the Labor Input: Comparing Efficiency Units and Hours Worked", manuscript, University of California, Los Angeles.

Hansen, G.D. and R. Wright (1992), "The Labor Market in Real Business Cycle Theory", *Federal Reserve Bank of Minneapolis Quarterly Review*, spring, 2-12.

King, R.G. (1990), "Money and Business Cycles," manuscript, University of Rochester.

Kydland, F.E. (1989), "The Role of Money in a Business Cycle Model," Institute for Empirical Macroeconomics Working Paper No.23.

Kydland, F.E. and E.C. Prescott (1982), "Time to Build and Aggregate Fluctuations," *Econometrica* 50, 1345-70.

Kydland, F.E. and E.C. Prescott (1990), "Business Cycles: Real Facts and a Monetary Myth," Federal Reserve Bank of Minneapolis *Quaterly Review* 14.

Kydland, F.E. and E.C. Prescott (1991), "Hours and Employment Variation in Business Cycle Theory", *Economic Theory* 1, 63-81.

Long, J.B. and C.I. Plosser (1983), "Real Busines Cycles," *Journal of Political Economy* 91, 39-69.

Lucas, R.E. Jr. (1972), "Expectations and the Neutrality of Money", *Journal of Economic Theory* 4, 103-124.

Lucas, R.E. Jr. (1989), "The Effects of Monetary Shocks When Prices Are Set in Advance", manuscript.

McGrattan, E.R. (1991), "The Monetary Effects of Distortionary Taxation," Institute for Empirical Macroeconomics D.P. 37.

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

Roche, M.J. (1991), *Fiscal Policy and the International Business Cycle*, Ph.D. Dissertation, Queen's University.

Rogerson, R. (1988), "Indivisible Labor, Lotteries and Equilibrium," *Journal of Monetary Economics*, 21, 3-16.

Stockman, A.C. and L.L. Tezar (1990), "Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements," University of Rochester W.P. No.255.

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

Table 1 Cyclical Properties of U.S. Time Series

Table 1a Volatility of Aggregates

	σ_Y	σ_C/σ_Y	σ_X/σ_Y	σ_N/σ_Y	σ_{Py}/σ_Y	σ_N/σ_{Py}
	1.74	0.48	3.15			
1. HSAI				0.82	0.50	1.64
2. ESNAI				0.94	0.48	1.95
3. HSNAI				1.01	0.70	1.44
4. EU				0.96	0.70	1.37

Table 1b Correlations Between Variables

	Y&C	Y&X	Y&N	Y&Py	N&Py	Y&P	Y&Rw
	0.75	0.90				-0.55	0.35
1. HSAI			0.87	0.58	0.10		
2. ESNAI			0.88	0.36	-0.13		
3. HSNAI			0.76	0.34	-0.35		
4. EU			0.74	0.41	-0.30		

Sources. All the data are taken from Hansen and Wright (1992) and cover the period 1955:3 to 1988:2 except for the correlations between Y and P and Y and Rw which are borrowed from Kydland and Prescott (1990) and cover the period 1954:1 to 1989:4.

Symbols. HSAI: Household Survey All Industries; ESNAI: Establishment Survey Nonagricultural Industries; HSNAI: Household Survey Nonagricultural Industries; EU: efficiency units; Y: Gross national product; C: Consumption of nondurables and services; X: Fixed investment; N: Hours worked; Py: productivity (output/hours worked); P: Implicit GNP deflator; Rw: Average hourly real compensation (business sector).

Table 2a Market-clearing Model - Volatility of Aggregates

Case	Standard Deviations					
	σ_Y	σ_C/σ_Y	σ_X/σ_Y	σ_N/σ_Y	σ_N/σ_{Py}	σ_{Py}/σ_Y
Data	1.74	0.48	3.15	0.82 - 1.01	1.37 - 1.95	0.48 - 0.70
Monetary Shocks	0.09	4.78	7.00	1.67	3.00	0.56
Fiscal Shocks	0.18	2.94	7.44	1.56	2.50	0.61
Technology Shocks	1.38	0.65	3.33	0.28	0.38	0.73
Monetary & Fiscal	0.21	3.19	7.29	1.52	2.70	0.57
Monetary & Technology	1.37	0.72	3.39	0.29	0.40	0.74
Fiscal & Technology	1.36	0.75	3.48	0.33	0.45	0.73
All Shocks	1.41	0.79	3.43	0.35	0.48	0.72

Table 2b Market-clearing Model - Correlations Between Variables

Case	Correlations						
	Y & P	Y & Rw	N & Py	Y & C	Y & X	Y & N	Y & Py
Data	-0.55	0.35	-0.35 - 0.10	0.75	0.90	0.74 - 0.87	0.34 - 0.58
Monetary Shocks	-0.38	-0.94	-0.98	0.99	-0.99	0.99	-0.94
Fiscal Shocks	0.97	-0.85	-0.94	-0.96	-0.99	0.98	-0.85
Technology Shocks	-0.99	0.99	0.96	0.98	0.99	0.98	0.99
Monetary & Fiscal	0.03	-0.88	-0.95	-0.35	-0.99	0.98	-0.88
Monetary & Technology	-0.36	0.99	0.87	0.91	0.97	0.93	0.99
Fiscal & Technology	-0.79	0.97	0.72	0.79	0.92	0.86	0.97
All Shocks	-0.38	0.97	0.68	0.76	0.90	0.85	0.97

Table 3a One-period Wage Contracts - Volatility of Aggregates

Case	Standard Deviations					
	σ_Y	σ_C/σ_Y	σ_X/σ_Y	σ_N/σ_Y	σ_N/σ_{Py}	σ_{Py}/σ_Y
Data	1.74	0.48	3.15	0.82 - 1.01	1.37 - 1.95	0.48 - 0.70
Monetary Shocks	0.92	0.41	3.92	1.58	2.69	0.59
Fiscal Shocks	0.44	1.02	2.93	1.52	2.91	0.52
Technology Shocks	1.45	0.66	3.34	0.32	0.46	0.70
Monetary & Fiscal	1.02	0.60	3.77	1.58	2.73	0.58
Monetary & Technology	1.66	0.58	3.55	0.93	1.40	0.66
Fiscal & Technology	1.46	0.71	3.37	0.55	0.78	0.70
All Shocks	1.78	0.63	3.52	0.95	1.46	0.65

Table 3b One-period Wage Contracts - Correlations Between Variables

Case	Correlations						
	Y & P	Y & Rw	N & Py	Y & C	Y & X	Y & N	Y & Py
Data	-0.55	0.35	-0.35 - 0.10	0.75	0.90	0.74 - 0.87	0.34 - 0.58
Monetary Shocks	-0.13	-0.99	-0.99	0.99	0.99	0.99	0.99
Fiscal Shocks	0.53	-0.98	-0.99	-0.53	0.18	0.99	-0.98
Technology Shocks	-0.99	0.99	0.89	0.99	0.99	0.95	0.99
Monetary & Fiscal	-0.06	-0.99	-0.99	0.37	0.86	0.99	-0.99
Monetary & Technology	-0.36	0.43	-0.24	0.97	0.99	0.77	0.43
Fiscal & Technology	-0.77	0.85	0.28	0.77	0.93	0.74	0.85
All Shocks	-0.42	0.39	-0.26	0.81	0.95	0.78	0.39

Table 4a Four-period Wage Contracts - Volatility of Aggregates

Case	Standard Deviations					
	σ_Y	σ_C/σ_Y	σ_X/σ_Y	σ_N/σ_Y	σ_N/σ_{Py}	σ_{Py}/σ_Y
Data	1.74	0.48	3.15	0.82 - 1.01	1.37 - 1.95	0.48 - 0.70
Monetary Shocks	2.47	0.47	3.81	1.58	2.67	0.59
Fiscal Shocks	0.65	0.52	1.85	1.55	2.89	0.54
Technology Shocks	1.48	0.65	3.36	0.38	0.58	0.66
Monetary & Fiscal	2.57	0.47	3.72	1.58	2.69	0.59
Monetary & Technology	2.78	0.52	3.70	1.37	2.28	0.60
Fiscal & Technology	1.66	0.63	3.16	0.72	1.11	0.64
All Shocks	2.84	0.53	3.63	1.36	2.24	0.61

Table 4b Four-period Wage Contracts - Correlations Between Variables

Case	Correlations						
	Y & P	Y & Rw	N & Py	Y & C	Y & X	Y & N	Y & Py
Data	-0.55	0.35	-0.35 - 0.10	0.75	0.90	0.74 - 0.87	0.34 - 0.58
Monetary Shocks	-0.05	-0.98	-0.99	0.98	0.99	0.99	-0.98
Fiscal Shocks	0.61	-0.99	-0.99	-0.61	0.59	0.99	-0.99
Technology Shocks	-0.99	0.98	0.87	0.99	0.99	0.95	0.98
Monetary & Fiscal	-0.01	-0.98	-0.99	0.87	0.98	0.99	-0.98
Monetary & Technology	-0.33	-0.42	-0.74	0.97	0.99	0.92	-0.42
Fiscal & Technology	-0.76	0.70	0.10	0.76	0.94	0.78	0.70
All Shocks	-0.33	-0.39	-0.73	0.89	0.98	0.91	-0.39

Table 5a Four-period Staggered Contracts - Volatility of Aggregates

Case	Standard Deviations					
	σ_Y	σ_C/σ_Y	σ_X/σ_Y	σ_N/σ_Y	σ_N/σ_{Py}	σ_{Py}/σ_Y
Data	1.74	0.48	3.15	0.82 - 1.01	1.37 - 1.95	0.48 - 0.70
Monetary Shocks	1.06	0.47	3.82	1.58	2.67	0.59
Fiscal Shocks	0.30	1.10	2.20	1.53	2.88	0.53
Technology Shocks	1.41	0.65	3.36	0.33	0.47	0.70
Monetary & Fiscal	1.12	0.54	3.66	1.58	2.68	0.59
Monetary & Technology	1.78	0.60	3.52	0.97	1.49	0.65
Fiscal & Technology	1.46	0.67	3.26	0.45	0.66	0.68
All Shocks	1.80	0.61	3.51	1.05	1.63	0.64

Table 5b Four-period Staggered Contracts - Correlations Between Variables

Case	Correlations						
	Y & P	Y & Rw	N & Py	Y & C	Y & X	Y & N	Y & Py
Data	-0.55	0.35	-0.35 - 0.10	0.75	0.90	0.74 - 0.87	0.34 - 0.58
Monetary Shocks	0.22	-0.98	-0.99	0.99	0.99	0.99	-0.98
Fiscal Shocks	0.80	-0.99	-0.99	-0.80	-0.37	0.99	-0.99
Technology Shocks	-0.99	0.99	0.92	0.99	0.99	0.96	0.99
Monetary & Fiscal	0.25	-0.98	-0.99	0.65	0.93	0.99	-0.98
Monetary & Technology	-0.28	0.36	-0.29	0.97	0.99	0.78	0.36
Fiscal & Technology	-0.85	0.93	0.54	0.85	0.96	0.82	0.93
All Shocks	-0.17	0.24	-0.37	0.87	0.97	0.80	0.24

Table 6. A comparison between real and contracting economies

	Standard deviations[a]					
	(Y^*/Y)	(N^*/N)	(Py^*/Py)	$\frac{(N/Y)^*}{(N/Y)}$	$\frac{(Py/Y)^*}{(Py/Y)}$	$\frac{(N/Py)^*}{(N/Py)}$
Hansen						
DL	.767	.422	.576	.553	.746	.730
IL	1.00[b]	.813	.424	.819	.418	1.92
Christiano Eichenbaum						
DL no gvt.	1.05	.440	.985	.419	.937	.446(.37)
DL with gvt.	1.11	.589	.904	.535	.818	.653(.58)
IL no gvt.	1.21	.706	.887	.581	.734	.793(.59)
IL with gvt.	1.32	.951	.844	.721	.648	1.12(.88)
MCM						
MFT	.801	.295	.864	.368	1.08	.341
1WCM						
MFT	1.01	1.02	.983	1.00	.973	1.03
4SCM						
MFT	1.02	1.14	.983	1.11	.961	1.16

Symbols. DL: Divisible labor; IL: Indivisible labor; MCM: Market-clearing model; 1WCM: One-period wage contracts model; 4SCM: Four-period staggered contracts model; MFT: Monetary, fiscal and technology (shocks).

a. For Christiano and Eichenbaum (1992), the ratios were calculated using their results obtained with *household data* except in the case of the ratio $(N/Py)^*/(N/Py)$ for which the results with *establishment data* were also available (numbers in parentheses in the last column).

b. Shock variance set to provide match of output variation with actual data.