The Dynamic Effects of Adjustment Costs

in a Model with

Stochastic Wage Staggering

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<u>Abstract</u>

I examine the role of labor adjustment costs and capital adjustment costs, in creating a propagation mechanism for money in a dynamic general equilibrium model, where households have market power in the labor market. In addition, staggered nominal wage rigidity is introduced into the model via Calvo. I find that labor adjustment costs help to improve the hump-shape response of output to monetary shocks, thus improving upon the monetary transmission mechanism. In contrast, capital adjustment costs weaken the monetary propagation mechanism, yet improve upon the statistical properties of the model. Together, reasonably large capital and labor adjustment costs obtain a hump-shape persistent response of output to a monetary shock and simultaneously help to generate statistical properties of the model that overall are more consistent with post-war U.S. data as compared to a model without adjustment costs.

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1. Introduction

In this paper, I introduce capital and labor adjustment costs into a dynamic general equilibrium model, where wages are determined in a staggered manner via Calvo, in order to improve upon the monetary propagation mechanism. In a recent paper, Kim (2003) introduces both price and wage rigidity and finds that while price rigidity does not improve the monetary propagation mechanism, wage rigidity via Calvo is able to achieve a persistent response in output to a monetary shock.[1] The amount of persistence however, is sensitive to the structural parameters in the model, mainly to the interest elasticity of money demand. Furthermore, including nominal rigidity of one year into the model, leads to the loss of some desirable statistical properties. First, monetary shocks alone lead to volatility of many macroeconomic variables, such as hours and output that are much higher than what is found in the data. This is consistent with the literature where nominal rigidity is introduced via Taylor (1979, 1980)[2]. Second, the correlation between output and other macroeconomic variables are not in line with the data. In this paper, I ask whether capital and labor adjustment costs can contribute to the monetary transmission mechanism created by Calvo type rigidity and simultaneously improve the statistical properties of the model. First, I find that introducing labor adjustment costs improves the persistence of output to a monetary shock irrespective of the value of the interest elasticity of money demand. Second, capital and labor adjustment costs lead to statistical properties of the model that are more in line with post-war U.S. data as

[1] Yun (1996) introduces price rigidity via Calvo into a cash-in-advance model and finds that price rigidity is not able to generate hump-shape responses to output. A more recent paper by Edge (2000) finds that including habit formation, time-to-build capital and investment adjustment costs into the Calvo price rigidity model leads to significant improvements.

[2] See for example Cho (1993) and Cho and Cooley (1995).

compared to Kim's model. Finally, while capital adjustment costs help to improve the statistical properties of the model they interfere with the persistence of output.

I introduce both capital and labor adjustment costs into a model similar to Kim (2003). Following Cogley and Nason (1995), these costs are additional costs incurred by firms and have a *direct* impact on production. I postulate quadratic adjustment cost functions as in Ambler, Guay and Phaneuf (2003), Fairise and Langot (1994) and Mendoza (1993). Ambler, etc. find an important role for labor adjustment costs in a cash-in-advance economy with Calvo type nominal wage staggering. In contrast to my model, they introduce labor adjustment as additional costs to production that do not alter output directly. In addition, the functional forms of the production function as well as households' preferences differ from the ones used in this paper. They find that without labor adjustment costs, staggered nominal wage rigidity via Calvo is sensitive to the elasticity of labor supply, which is not the case here.[3] Lastly, Ambler, etc. focus on labor adjustment costs while I find a role for capital adjustment costs as well.

The adjustment costs introduced in this paper, both satisfy two empirical findings. First, these adjustment costs are small and second they play an important role in altering the firm's production process; as found by Jaramillo, etc. (1993), Davis and Haltiwanger (1990) and Summers (1981).

I follow Kim (2003), Christianno, Eichenbaum and Evans (2001) – henceforth CEE , Erceg (1997) among others by introducing nominal wage rigidity in the spirit of Calvo into a labor market where households choose wages. I assume that households have market power in the labor market, and consequently households choose nominal

[3] Specifically, one can show that introducing Calvo nominal wage rigidity of one year into Hansen's indivisible labor economy with money, does not lead to a hump shape response in output, when a monetary shock is introduced. The response of output falls fallowing the initial increase.

wages as part of their decision-making. This implies that in the labor market each household is a monopolistic supplier of a differentiated labor input[4]. Subsequently, an intermediary, such as an employment agency, uses Dixit-Stiglitz technology to transform individual labor services into an aggregate labor input that is sold to the final-goods producer. The final-goods firm produces output in a perfectly competitive environment.

Calvo type staggering implies that at the beginning of each period a fraction of households is able to reoptimize wages while the rest of the households revise their wage according to a rule. Whether a household is able to revise their wage is determined with a positive probability at the beginning of the period. I consider nominal wage rigidity of four quarters. This is based on the empirical findings of Levin (1991) and Taylor (1993) among others, who find that on average the most common length of time for which nominal wages are set is one year.

Without adjustment costs, nominal wage rigidity alone does propagate monetary shocks, however to what extend does depend on the interest elasticity of money demand, ζ_m. For smaller values of ζ_m the impulse response functions of output show more dynamics than for higher values. Hence, the results are sensitive to the interest elasticity of money demand parameter. I find that by introducing reasonably large labor adjustment costs (LAC), I can obtain persistence in output – specifically a hump-shape response of output – similar to Kim even for high values of ζ_m that would otherwise lead to lower persistence. Hence, LAC improve the transmission mechanism for monetary shocks. This is not the case for capital adjustment costs (KAC). I find that KAC slightly weaken the monetary transmission mechanism for every value of ζ_m, hence I do not

[4] Griffin (1996) provides microeconomic evidence of this feature, reporting that the estimated elasticity of substitution between labor skills is greater than one in U.S. firms.

obtain strong persistence when ζ_m is high and LAC are zero. Finally, larger LAC are needed to obtain strong persistence in output when both LAC and KAC are present and ζ_m is high.

Nominal wage rigidity alone leads to an economy that is highly volatile. By introducing capital or labor adjustment costs this volatility is reduced. In both cases, the firm has an incentive to alter labor or capital only slightly over time and hence the volatility of output and hours, for example, is lower. Together, capital and labor adjustment costs further decrease volatility and lead to results that are more consistent with the U.S. data.

Nominal wage rigidity also leads to high correlations between output and many other macroeconomic variables, such as hours, productivity and interest rate. With adjustment costs, the correlations are decreased as last period capital and hours directly affect output. Specifically, the correlation between output and productivity and output and interest rate both decrease, when capital and labor adjustment costs are introduced. In both cases the results are driven by the presence of capital adjustment costs. Hence, capital adjustment costs lead to improvements in the statistical properties of the model. Overall, I find that a model with both labor and capital adjustment costs leads to a hump-shape respond in output, output persistence and generates statistical properties that closely match the U.S. post-war data.

The remainder of this paper is organized as follows. Section 2 presents the model economy, where nominal wage rigidity is discussed and a wage rule formulated. The equilibrium in this economy is defined in section 3. Section 4 follows with a brief description of the solution method. The model is calibrated in section 5. The findings of the model that include impulse response functions and statistics are discussed in section 6. Section 7 concludes the paper.

2. The Model

The economy consists of final-goods firms, an intermediary, households, and the government. The final-goods firms produce output using technology that is subject to technology shocks. In contrast to Kim (2003), output in the economy is produced by perfectly competitive firms, and no price rigidity in the output market is present. In addition, firms face costs when adjusting labor hours and capital that effect the output level directly. The aggregate labor hours that firms use in production are purchased from an intermediary, such as an employment agency. The intermediary transforms differentiated labor services obtained from households into an aggregate labor input. Households are composed of infinitely lived-agents, who gain utility from leisure, consumption and real money balances. The key characteristic of this economy is that households have market power in the labor market. This implies that households are monopolistic suppliers of differentiated labor services. In the presence of Calvo type nominal wage rigidity, a fraction of households reoptimize nominal wages every period while the remaining households use a nominal wage rule to revise wages. Lastly, the economy also includes a government sector, whose role is to inject money into the economy through a lump-sum transfer.

2.1 Final-Goods Firms

The final-goods firms produce output using the following technology

$$Y_t = e^{Z_t} K_t^{\theta} H_t^{1-\theta} - LAC_t - KAC_t \qquad 0 < \theta < 1, \tag{1}$$

where Y is output produced in this economy, K is capital stock and H is total labor purchased from the intermediary.[5] The parameter θ represents capital's share in total income. The production function is subject to a technology shock z_t that alters total factor productivity. As in the real business cycle literature, we let z_t evolve according to the following law of motion

$$z_{t+1} = \rho_z z_t + \varepsilon_{t+1} \qquad 0 < \rho_z < 0, \tag{2}$$

where ε is normally distributed with mean zero and a standard deviation of σ_Z. Furthermore, firms incur labor adjustment costs LAC_t and capital adjustment costs KAC_t, both of which effect output directly in period t. The adjustment costs functions take the following forms

$$LAC_t = \alpha_H \left(\frac{H_t}{H_{t-1}} - 1 \right)^2 H_t \qquad \alpha_H \geq 0, \tag{3}$$

$$KAC_t = \alpha_K \left(\frac{K_t}{K_{t-1}} - 1 \right)^2 K_t \qquad \alpha_K \geq 0, \tag{4}$$

where α_H and α_K are labor and capital adjustment costs' parameters respectively. The adjustment cost functions are quadratic, convex and symmetric. Moreover, the functional form of the output function exhibits constant returns-to-scale in its inputs, K_t, H_t, K_{t-1} and H_{t-1}.[6] When $\alpha_H > 0$, firms incur positive labor adjustment costs if the aggregate labor differs across periods, and none if labor hours are not fluctuating.

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[5] Cogley and Nason (1995) consider this type of output function in order to obtain endogenous output dynamics in standard RBC model without money. Their findings indicate that labor adjustment costs are able to lead to internal propagation mechanism while capital adjustment costs do not.
[6] Thus, we can assume a single representative firm, and our results do not depend on the number of firms.

Similarly, when $\alpha_K > 0$, firms incur positive capital adjustment costs as long as capital differs across periods.

The adjustment cost functions are such that today's labor hours/capital effect not only today's adjustment costs but next period's adjustment costs as well. This implies that in determining today's labor hours/capital firms take into account the impact that today's value of labor hours/capital will have on next period's adjustment costs. Thus, the maximization problem faced by a representative firm is linked intertemporaly, in which case, solving a static problem is no longer equivalent to solving an intertemporal problem, as is the case in a standard RBC model. In contrast, due to the presence of labor adjustment costs and capital adjustment costs, the firm's problem is to maximize the discounted present value of future profits Π_t

$$\Pi_t = \sum_{t=0}^{\infty} \upsilon_t^t \left(\frac{P_t Y_t - W_t H_t - R_t K_t}{P_t} \right), \qquad 0 < \upsilon < 1, \tag{5}$$

where Y_t is given by (1), W_t is the aggregate nominal wage, P_t is the price level, and R_t is the nominal rental rate. The firm discounts future profits by υ. Given the intertemporal nature of the firm's problem, the first-order condition of the firm that gives the real wage rate is

$$\begin{aligned} \frac{W_t}{P_t} = (1-\theta)e^z K_t^{\theta} H_t^{-\theta} - \alpha_H \left(\frac{H_t}{H_{t-1}} - 1 \right)^2 - 2\alpha_H \left(\frac{H_t}{H_{t-1}} - 1 \right) \frac{H_t}{H_{t-1}} \\ + \underset{t}{E} \left[2\alpha_H \upsilon_{t+1} \frac{P_{t+1}}{P_t} \left(\frac{H_{t+1}}{H_t} - 1 \right) \frac{H_{t+1}^2}{H_t^2} \right] \end{aligned} \tag{6}$$

where the last term shows the effect on future labor adjustment costs from today's change in labor hours. Hence, the last term in (5) is the result of the firm's maximization problem being intertemporal. υ_{t+1} is the firm's discount factor that equals to the household's market rate of discount.[7]

The rental rate reflects the intertemporal linkage as well. The first order condition is given by

$$\frac{R_t}{P_t} = (1\text{-}\theta)e^z K_t^{\theta\text{-}1} H_t^{1\text{-}\theta} - \alpha_K \left(\frac{K_t}{K_{t\text{-}1}}\text{-}1\right)^2 - 2\alpha_K \left(\frac{K_t}{K_{t\text{-}1}}\text{-}1\right)\frac{K_t}{K_{t\text{-}1}} + \underset{t}{E}\left[2\alpha_K \upsilon_{t+1} \frac{P_{t+1}}{P_t}\left(\frac{K_{t+1}}{K_t}\text{-}1\right)\frac{K_{t+1}^2}{K_t^2}\right] \tag{7}$$

where equation (7) says that firms purchase capital until the costs of one additional unit of capital equals the benefits of that additional capital unit. Again, the last term in (7) indicates that the firm takes into account the effect that today's capital will have on next period's capital adjustment costs and hence output.

2.2 Intermediary

Following Kim (2003) and CEE (2001), I assume that a given household is a monopolistic supplier of a differentiated labor input H_{it}. An intermediary, such as an employment agency, uses the following Dixit-Stiglitz technology to transform individual labor services into an aggregate labor input H_t that it sells to the final-goods producers:

$$H_t = \left(\int H_{it}^{\lambda} di\right)^{\frac{1}{\lambda}} \qquad 0 < \lambda < 1 \qquad i \in [0,1], \tag{8}$$

where λ governs the elasticity of substitution between different H_{it}.[8] The intermediary chooses H_{it} by maximizing his profits

[7] The firm's discount factor is further discussed in section 3.

[8] The elasticity of substitution between differentiated labor units is $\frac{1}{1-\lambda}$.

$$\Pi_t^{IF} = W_t H_t - \int W_{it} H_{it} di, \qquad (9)$$

where W_{it} is the individual wage rate and Π_t^{IF} are profits of the intermediary. From the first-order condition for the intermediary it follows that the demand for individual labor hours is given by

$$H_{it} = \left(\frac{W_{it}}{W_t}\right)^{\left(\frac{1}{\lambda-1}\right)} H_t, \qquad (10)$$

where W_t is related to the individual wage rate via

$$W_t = \left(\int W_{it}^{\frac{\lambda-1}{\lambda}} di\right)^{\frac{\lambda-1}{\lambda}}. \qquad (11)$$

To obtain (11) the intermediaries zero profit condition is used.

2.3 Households

The economy consists of a continuum of heterogeneous infinitely-lived households indexed by i, where $i \in [0,1]$. I follow Chari, Koheo and McGrattan (1998) (henceforth CKM) and Kim (2003) and introduce money into the utility function, whereby households obtain utility from money, consumption, and leisure. Households are assumed to be homogenous with respect to consumption and asset holdings, and heterogeneous with respect to the wage rate and hours worked.[9] Moreover, wages are set in a staggered manner in the spirit of Calvo. Hence, at any given time period, a random fraction of households optimally set their wages while the remaining households revise their wages according to a nominal wage rule.

[9] I assume that consumption for all households is pooled and hence consumption choices are identical across households. Actually, I assume that individual households have access to complete markets for contingent claims, whereby they are able to insure themselves against any idiosyncratic consumption risk that may arise due to the fact that they differ with respect to wage income.

Household i maximizes discounted life-time utility, where the utility function is identical to the one used by Kim (2003) and is of the following form[10]

$$U(C_t, 1-H_t, \frac{M_t}{P_t}) = \left[\left(C_t^{\eta} + b\left(\frac{M_t}{P_t}\right)^{\eta} \right)^{\frac{1}{\eta}} \left(1-H_{it}\right)^{\chi} \right]^{1-\sigma} / \left(1-\sigma\right), \qquad (12)$$

subject to the budget constraint

$$C_t + K_{t+1} - (1-\delta)K_t + \frac{M_t}{P_t} + \frac{B_t}{P_t} \le \frac{W_{it}H_{it}}{P_t} + \frac{R_t K_t}{P_t} + \frac{T}{P} + \frac{M_{t-1}}{P_{t-1}} + Q_{t-1}\frac{B_{t-1}}{P_t} + s_i \Pi_t . \qquad (13)$$

Households' expenditure consists of consumption C_t, investment $K_{t+1} + (1-\delta) K_t$, where δ is the capital depreciation rate, real money balances M_t/P_t, and bond holdings B_t/P_t. The total income available to households comes in the form of labor income, return on capital rental, government lump-sum transfer T_t/P_t, money balances carried over from previous period, principle plus interest income on last period's bond holding, where Q_t is the gross nominal interest rate, and its share of profits obtained from the final goods firm. The parameters in the utility function include the parameter η governing the interest elasticity of money demand, the weight on leisure χ, risk aversion σ, and the coefficient on real money balances b.

The households decision making can be thought of in two steps. First, a household either reoptimizes or revises its wage. Second, given W_{it}, the household maximizes its utility over consumption, capital, money balances, and bond holdings. The first step is postponed till section 2.4.

The first-order-conditions for the households over (C_t, K_{t+1}, M_t, B_t) given W_{it} are:

[10] Kim (2003) follows CKM (2000) by considering a utility function that has constant elasticity of substitution in consumption and real money balances, and is CRRA in leisure and the term reflecting consumption and real money balances.

$$\frac{\partial U_t}{\partial C_t} = \Lambda_{it}, \tag{14}$$

$$\Lambda_{it} = \beta \underset{t}{E}\left[\Lambda_{it+1}\left(\frac{R_{t+1}}{P_{t+1}} + 1 - \delta\right)\right], \tag{15}$$

$$\frac{\partial U_t}{\partial m_t}\frac{1}{P_t} = \Lambda_{it}\frac{1}{P_t} - \beta \underset{t}{E}\left[\frac{\Lambda_{it+1}}{P_{t+1}}\right], \tag{16}$$

$$\frac{\Lambda_{it}}{P_t} = Q_t \beta \underset{t}{E}\left[\frac{\Lambda_{it+1}}{P_{t+1}}\right], \tag{17}$$

where $\frac{\partial U_t}{\partial m_t} = b\Lambda_{it}\left(\frac{M_t}{C_t P_t}\right)^{\eta-1}$ and Λ_{it} is the Lagrange multiplier on an individual household's budget constraint. Equation (15) is the standard Euler equation for the intertemporal consumption choices. Substituting (17) into (16) and using the definition of $\frac{\partial U_t}{\partial m_t}$, I obtain the money demand function

$$b\left(\frac{M_t}{C_t P_t}\right)^{\eta-1} = 1 - \frac{1}{Q_t}. \tag{18}$$

2.4 Staggered Wage Setting via Calvo

In this section I derive the rule for W_{it}. Given the stochastic nature of Calvo wage staggering, there is a positive probability φ that household i will revise its wage at time t, implying that $i \in rev(t)$. Similarly, with probability $1-\varphi$ households i will reoptimize its wage at time t, hence $i \in opt(t)$.

Household $i \in rev(t)$ revises its wage according to a wage rule commonly used in the literature, as in Kim (2003), CEE (2001) and Erceg, Henderson and Levin (2000) given by

$$W_{it} = \bar{\Pi} W_{it-1}, \tag{19}$$

where $\bar{\Pi}$ is the steady state growth rate of nominal wage rage. In contrast, household $i \in opt(t)$ faces a dynamic problem when choosing wages. At time t, household $i \in opt(t)$ does not know whether it will be able to reoptimize next period or not. If it is not able to reoptimize, then it will have to revise its wage via (19). As a result its wage at time t+1 will depend on the wage it chooses at time t, and hence the problem faced by household $i \in opt(t)$ is dynamic.

The first-order-condition with respect to wages is

$$-E_t \sum_{j=0}^{\infty} (\beta\varphi)^j \frac{\partial U_{it+j}}{\partial H_{it+j}} \frac{\partial H_{it}}{\partial W_{it}} = E \sum_{j=0}^{\infty} (\beta\varphi)^j \frac{\Lambda_{t+j}}{P_{t+j}} \bar{\Pi}^j \left(H_{ij} + W_{it} \frac{\partial H_{ij}}{\partial W_{it}} \right), \tag{20}$$

which states that household $i \in opt(t)$ equates the present discounted disutility from working to the present discounted value of utility of labor income. I substitute the following term $\frac{\partial H_{it}}{\partial W_{it}} = \bar{\Pi}^{\left(\frac{j\lambda}{\lambda-1}\right)} H_{t+j} W_{t+j}^{\left(\frac{1}{1-\lambda}\right)}$ into equation (20) and solve for W_{it}. This yields

$$W_{it} = -\frac{E_t \sum_{j=0}^{\infty} (\beta\varphi)^j \frac{\partial U_{it+j}}{\partial H_{it+j}} \bar{\Pi}^{\left(\frac{j}{\lambda-1}\right)} H_{t+j} W_{t+j}^{\left(\frac{1}{1-\lambda}\right)}}{\lambda E_t \sum_{j=0}^{\infty} (\beta\varphi)^j \frac{\Lambda_{it+j}}{P_{t+j}} \bar{\Pi}^{\left(\frac{j\lambda}{\lambda-1}\right)} H_{t+j} W_{t+j}^{\left(\frac{1}{1-\lambda}\right)}}. \tag{21}$$

Notice that this expression says that reoptimizing households take into account the future only if they are not able to reoptimize in the future. The probability that household i will not be able to reoptimize for j periods is φ^{j}. If φ equals zero, I get the standard condition in flexible wage models that is

$$\Lambda_{it}\frac{W_t}{P_t} = -\frac{1}{\lambda}\frac{\partial U_{it}}{\partial H_{it}}, \tag{22}$$

where $\frac{1}{\lambda}$ is the markup over the perfectly competitive wage.

2.5 Government

For comparison purposes I use the exogenous monetary policy rule as used by Kim (2003). Hence, in conducting monetary policy, the government prints money and injects it into the economy according to

$$M_{t+1} = e^{\mu_t} M_t, \tag{23}$$

where the money growth rate is $e^{\mu_t} - 1$ in period t. Hence, μ_t is a random variable governing the growth rate of money supply, and is assumed to evolve according to the autoregressive process

$$\mu_{t+1} = \rho_\mu \mu_t + \xi_{t+1} \tag{24}$$

where ρ_μ falls in (0,1). To ensure that the budget constraint is binding, μ_t must be positive in every period. This can be assured by assuming that ξ is log-normally distributed with mean $(1-\rho_\mu)\bar{\mu}$ and standard deviation σ_μ, where $\bar{\mu}$ represents the average growth rate of money.

3. Equilibrium

First, I define the discount factor used by the firm υ_{t+1}. The firm discounts future profits at the household's market rate of discount. The assumption of complete markets for contingent claims implies that all households share the same market rate of discount. Hence, the firm discounts next period profits by

$$\upsilon_{t+1} = \beta \frac{\Lambda_{t+1}}{\Lambda_t}. \qquad (25)$$

An equilibrium for this economy consists of a set of allocations for the households $C_t, K_{t+1}, M_t, B_t,$ and H_{it}; a set of allocations for the final goods firm K^F and H^F; allocations for the intermediary H_t and H_{it}; and prices P_t, W_{it}, R_t and Q_t such that the following conditions are satisfied: i) household $i \in opt(t)$ takes all prices (but its own) as given to solve for W_{it} via (21); ii) given all prices household i maximizes its lifetime utility using (12) subject to the constraint in (13); iii) given all prices the intermediary solves its maximization problem in (9); iv) given all prices the final-goods firm solves its maximization problem in (5); v) all markets clear.

I focus on a symmetric and stationary equilibrium. A symmetric equilibrium implies that all household $i \in opt(t)$ make identical decisions, when choosing W_{it}.[11] To impose stationarity I transform all nominal variables that grow in steady state. These variables grow at positive growth rate of money, therefore all nominal variables are divided by $\bar{\mu}^t$.

4. Solution Method

The model is solved using the method of undetermined coefficient (Campbell, 1994). The results of this procedure are recursive equilibrium laws of motion for the variables of

[11] I assume that all households have the same share of profits from the firm.

interest. I start by postulating a linear relationship between the decision variables and the state variables. A general representation is given by

$$\begin{aligned} X_t &= AX_{t-1} + Bw_t \\ V_t &= CX_{t-1} + Dw_t \,, \end{aligned} \tag{26}$$

where X_t is an endogenous state vector, V_t is a vector of other endogenous variables and w_t is a vector of stochastic processes. The stochastic processes considered here are the technology shock and the money growth shock. The objective is to solve for the matrices A, B, C, and D in order to obtain equilibrium decision rules for X_t as well as equilibrium decision rules for V_t .

Since the equations in (23) are postulated recursive laws of motion, the coefficients in matrices A, B, C, and D are undetermined. In order to solve for these matrices I log-linearizing the equations characterizing the equilibrium around the steady state. This includes the first-order-conditions of the households and firms, the budget constraint and the output function.[12] Together, the postulated laws of motion and the log-linearized equilibrium equations from the model are used to solve for the undetermined coefficients. Here I make use of an algorithm formulated by Uhlig (1999).

5. Calibration

The model is calibrated to post-war U.S. data from 1954:1 to 1999:4. The capital's share of total income θ is calibrated to be 0.4, and δ is set equal to 0.025 corresponding to a 10% annual depreciation rate. The value of β is set to match the capital-output ratio, thus the quarterly value of β is 0.989. The value of χ (=1.3) is chosen so that at the

[12] The equations characterizing the equilibrium in log deviation form are given in the Appendix (Section 8).

steady state, households spends 1/3 of their time working. The elasticity of individual labor demand λ is set equal to 0.9.

I follow CKM (2000) to calibrate η and b using money demand literature. Equation (18) can be rewritten in log form as

$$\log\frac{M_t}{P_t} = -\frac{1}{\eta-1}\log b + \log C_t + \frac{1}{\eta-1}\log\left(1-\frac{1}{Q_t}\right). \tag{27}$$

I regress log consumption velocity of money on the interest rate using M1, Consumer Price Index, Consumption (services, durables, nondurables), and 3 month U.S. Treasury bill rate for 1959:01 to 1999.4. The estimated value of η is -1.27 with a standard error of 0.638, corresponding to an interest elasticity of 0.44.[13] These estimates are consistent with the findings of Mankiw and Summers (1986). The parameter b is estimated to 4.61.[14]

The values of γ and σ_z are chosen following Prescott (1986), hence I set ρ_z = 0.95 and σ_z = 0.007. The parameter determining money supply ρ_μ, standard deviation σ_μ, and the average growth rate of money $\bar{\mu}$ are selected following Cooley and Hansen (1995). I take logs of equation (23), combine it with equation (24), leading to an estimated autoregressive process as follows

$$\Delta\log M_t = \underset{(0.001)}{0.0052} + \underset{(0.062)}{0.552}\Delta\log M_{t-1} + \xi_t,\ \hat{\sigma}_\mu = 0.0089, \tag{28}$$

which implies that ρ_μ = 0.55, σ_μ = 0.0089 and $\bar{\mu}$ = 0.012. The correlation between the two shocks in this economy z_t and μ_t is assumed to be zero.

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[13] Kim sets η = -17.56 while CKM find η to be -1.56. I find the results to be strongly sensitive to this parameter and I will discuss it further in section 6.

[14] Kim sets b = 1.3472, however I find that the conclusions of this model do not depend on b.

The parameters α_K and α_H cannot be calibrated in the standard sense. Relying on empirical literature, I follow Shapiro (1995) and set the value of $\alpha_K = 1.1$ and the value of $\alpha_H = 0.18$. These values lead to average adjustment costs of about 0.1% of GDP in both cases. This is consistent with the results of Summers (1981) and Jaramillo, Schiantarelli and Sembenelli (1993) that adjustment costs are small but significant. Finally, Levin (1991) and Taylor (1993) find that majority of nominal wage contracts are set for 1 year, this implies a φ=0.75.

Table 1 summarizes the parameters of the model

TABLE 1: Parameter Values

θ	β	δ	χ	λ	η	b	ρ_z	σ_z	ρ_μ	σ_μ	$\bar{\mu}$	α_K	α_H	φ
0.4	0.989	0.025	1.3	0.9	-1.27	4.61	0.95	0.007	0.55	0.0089	0.012	1.1	0.18	0.75

6. Findings

6.1 Impulse Response Functions to a Monetary shock

To analyze the impact of adjustment costs in my model, I consider alternative parameter values for α_K and α_H when η=-1.27. All results are shown in Figure 1. Panel 1 (Basic Model) shows the results when α_K and α_H are set to zero and η=-1.27. Output increases right away in response to a monetary shock and continues to increase very slightly next period, followed by a steadily decrease for the next several periods. Although output does stay above its steady state level for several years after the shocks, the initial response lacks the hump-shape obtained by Kim (2003) when η=-17.52, shown in the same panel. Notice that while the initial increase in output in Kim's model is lower, output continues to increase for three periods after the initial increase, hence having a more hump shape response. Panel 1 indicates that the results are sensitive to the interest elasticity of money demand[15].

Next, I ask whether labor adjustment costs or capital adjustment costs can improve the initial dynamics of output. I start by introducing labor adjustment cost only. Panel 2 shows impulse response functions when $\alpha_K = 0$, $\alpha_H > 0$ and $\eta = -1.27$ as well as the Basic Model. Compared to output response where $\alpha_H = 0$, with positive LAC the initial impact on output is lower, however output continues to rise for the next two periods. The response defers from Kim's as well. While in Kim's model output increases for three periods, in my model, given $\alpha_K = 0$ and $\alpha_H = 0.18$, the initial increase in output is followed by two periods of a rise in output. LAC create persistence in output but larger LAC are needed to attain the hump-shape respond similar to Kim's. I increase LAC so that $\alpha_H = 0.5$, still keeping KAC at zero. As shown in Panel 2 these additional adjustment costs that the firm faces further increase the initial responds of output.[16] In this case the hump-shape response of output is stronger than in Kim's model.

Nominal wage rigidity together with LAC lead to persistent output dynamics, when the economy is subject to a monetary shock, by improving the monetary transmission mechanism. Nominal wage rigidity causes firms to increase labor when faced with a positive monetary shock, due to lower marginal productivity of labor. In the presence of positive LAC firms increase labor slowly overtime in order to smooth out LAC costs. My findings indicate that for reasonably high LAC nominal wage rigidity together with LAC lead to strong persistence in output, even for a low value of η.

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[15] The empirical results regarding this parameter depend on the functional form of the money demand function, which are under debate.
[16] Note that in this case LAC are still on average less than 0.1% of output.

Next, I ask weather KAC will create such persistence in output as well. In panel 3, I show the impulse response functions when α_K = 1.1, α_H = 0 and η = -1.27. In the Basic Case output increases very slightly after its initial increase. In this case KAC weaken the monetary transmission mechanism by reducing the interest rate effect of a change in money supply. Hence, the persistence is lower.[17] With positive KAC the impact of a monetary shocks dissipates faster than in a model with LAC only or in a model without any AC. Specifically, when introducing KAC, eight years after the shock the response is close to 0.05, yet in a model with LAC only the response is around 0.25. Similarly, in a model without any type of LAC as in Panel 1, the response again is higher, close to 0.2.

In Panel 4, I show the impact of LAC and KAC together. Since LAC improve the monetary transmission mechanism and KAC weaken it, large LAC will be needed to have output dynamics similar to Kim. The dynamics when α_H = 0.18 and 0.5 are slightly weaker than in Kim's model. Increasing LAC further so that α_H = 1 causes a hump-shape response in output that is as strong as in Kim. These LAC are on average slightly over 0.1%.

In sum, I find that LAC help to strengthen the monetary transmission mechanism, whereby LAC act together with nominal wage rigidity to increase output persistence. This is the case for values of η that without LAC do not lead to strong hump-shape responses. My findings indicate that KAC do not improve the propagation mechanism of monetary shocks in my model. Finally, when both KAC and LAC are introduced and η= -1.27, larger LAC are needed for output to be as persistent as in Kim (2003). However,

[17] In the case of η= -17.53 the impact of KAC is similar.

for the low value of η, a model with both LAC and KAC does better in obtaining output dynamics than does a model without adjustment costs.

6.2 Simulation Results

Table 2 and 3 show the simulation results in the form of standard deviations and correlations. The first row of table 2 shows statistical properties of some key macroeconomic variables in the post-war US economy. This is followed by simulation results for the Basic Model – a model without adjustment costs – with η taking on the value of -1.27 and -17.56 respectively. In both cases volatility of hours is larger than what is observed in the data. The volatility of output is slightly bigger as well. Volatility of interest rates is quite small in this model, and matches the standard deviation of interest rate on a 10 year to maturity bond[18]. The correlation between output and hours in both models is high and matches the data. When it comes to the correlation between output and interest rate both are much too high. The model does not do well in matching the negative correlation between output and price. Lastly, the correlation between output and productivity is not matched well by either model. While the basic model with my value of η = -1.27 leads to a countercyclical productivity, with Kim's value the correlation is almost zero. In summary, a model with nominal wage rigidity in the spirit of Calvo produces standard deviation of labor and to some extend output that are large. In addition, the correlation between output and productivity does not match the data, and finally, the correlation between output and interest rate is too high while the correlation between output and price is of the wrong sign.

[18] It does not match well the short term interest rate, such as 3 month treasury bill that has volatility of 1.18.

Table 3 shows results when adjustment costs are introduced into the basic model with η equal to -1.27. In Panel A, I introduce labor adjustment costs only given $\alpha_H = 0.18$ and $\alpha_H = 0.50$. The behavior of the model under both parameter values is similar. The volatility of both output and hours falls. The correlation between output and hours and interest rate respectively both fall and more closely match the data. However, the correlation between output and productivity as well as price continues to be of the wrong sign as compared to the data. When I introduce capital adjustment costs – Panel B – as the only source of additional adjustment costs, the standard deviations as well as the correlations are improved upon. Specifically, the volatility of output falls from 2.6 to 1.51 and the correlation between output and interest rate falls to 0.45. In addition, although the correlation between output and price is still positive, it falls by almost 70% to 0.14. However, the correlation between output and productivity still remains negative, although it falls to -0.14.

Now I consider an economy with both capital and labor adjustment costs. I consider the same value for the capital adjustment costs parameter. In the case of α_H, I use the same values as in Panel A. When both capital and labor adjustment costs are introduced, the volatility of both hours and output fall drastically[19]. Thus, the volatility of hours and output more closely matches the data as compared to the results in Table 2 where adjustment costs are zero. With respect to interest rate and price, the volatility of interest rate is slightly lower and hence further away from the data, while the standard deviation of price is slightly higher.

[19] Note that none of the models discussed here are able to obtain standard deviation of output that is higher than the standard deviation of hours.

Next, I look at the correlations. While the basic model (η= -1.27) leads to a negative correlation between output and productivity that is in conflict with the data, introducing both labor and capital adjustment costs leads to a correlations of zero which is similar to the basic model with Kim's parameter.[20] The individual results in Panel A and B indicate that capital adjustment costs drive most of the results on the procyclicity of productivity. Same is true for the correlation between output and interest rate. In this case both adjustment costs individually lead to a fall in the correlation and together obtain a correlation more closely matching the data than does the basic model or Kim's model. The correlation between output and hours is best matched by a model with labor adjustment costs only. Once capital adjustment costs are introduced the correlation falls and is slightly below the observed value. Lastly, none of the models are able to obtain the negative correlation between output and price observed in the data. The basic model with η= -17.56 and the models with both capital and labor adjustment costs come closest in matching the data, yet the values are still of the wrong sign.

7. Conclusion

I introduce capital and labor adjustment costs into a dynamic general equilibrium model with nominal wage rigidity via Calvo. Without adjustment costs the model generates strong output persistence, however this result is dependent on the value of the interest elasticity of money demand parameter. In the case of high interest elasticity of demand the impulse response of output to monetary shocks looses its hump-shape response. Furthermore, the model's statistical properties are inconsistent with the data. While

[20] This is the best result, and further sensitivity analysis shows that higher KAC and LAC are needed to obtain a strong positive correlation.

Calvo type nominal wage rigidity improves the propagation mechanism of monetary shocks, it leads to high standard deviation of output and labor. The correlation of output and other key variables is in many cases too high or of the wrong sign.

I find that capital and labor adjustment costs together improve upon the results. In the case of impulse response functions, I find that labor adjustment costs alone improve the propagation mechanism of monetary shocks irrespective of the value of the interest elasticity of money demand, but alone do not improve upon the statistical results to a great extent. Capital adjustment cost alone lead to large improvement in the statistical properties of the model, but in terms of persistence they weaken the monetary propagation mechanism. Together, reasonably large capital and labor adjustment costs improve upon a number of statistical properties and still obtain a hump-shape persistent response of output to a monetary shock.

Finally, although I use a monetary policy rule that is exogenous in order to compare with Kim (2003), in further research a rule that responds to changes in technology shocks, as in Gali (1999), should be considered.

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8. Appendix

8.1.1 Aggregation over Households

The economy has two types of agents, those who optimize over wages denoted here by i=0 and those who revise their wages denoted by i=1. The aggregation of household equations over i yields

$$\Lambda_t = \left[C_t^{\eta} + b\left(\frac{M_t}{P_t}\right)^{\eta} \right]^{\frac{1-\sigma-\eta}{\eta}} C_t^{\eta-1} \left[\int_{i\in[0,1]} \left(1-H_{it}\right)^{(1-\sigma)\chi} di \right], \tag{A1}$$

$$\Lambda_{0t} = \left[C_t^{\eta} + b\left(\frac{M_t}{P_t}\right)^{\eta} \right]^{\frac{1-\sigma-\eta}{\eta}} C_t^{\eta-1} \left(1-H_{0t}\right)^{(1-\sigma)\chi} , \tag{A2}$$

$$\Lambda_t = \beta \mathop{E}_t \left[\Lambda_{t+1}\left(\frac{R_{t+1}}{P_{t+1}} + 1 - \delta\right) \right], \tag{A3}$$

$$\frac{\Lambda_t}{P_t} = Q_t \beta \mathop{E}_t \left[\frac{\Lambda_{t+1}}{P_{t+1}} \right], \tag{A4}$$

$$b\left(\frac{M_t}{C_t P_t}\right)^{\eta-1} = 1 - \frac{1}{Q_t}, \tag{A5}$$

$$w_t^* = \frac{\chi E_t \sum_{j=0}^{\infty} (\beta\varphi)^j \left[\left(c_{t+j}^{\eta} + b\left(\frac{m_{t+j}}{p_{t+j}}\right)^{\eta} \right)^{\frac{1-\sigma}{\eta}} \left(1 - \left(\frac{w_{t+j}^*}{w_{t+j}}\right)^{\frac{1}{\lambda-1}} H_{t+j} \right)^{\chi-1-\chi\sigma} w_{t+j}^{\frac{1}{1-\lambda}} H_{t+j} \right]}{\lambda E_t \left[(\beta\varphi)^j \frac{\Lambda_{i,j+t}}{p_{j+t}} w_{t+j}^{\frac{1}{1-\lambda}} H_{t+j} \right]}, \tag{A6}$$

where $i \in opt(t)$.

8.1.2 Other Equation

The aggregate nominal wage is given by

$$\hat{w}_t = \varphi \hat{w}_{t-1} + (1-\varphi)\, \hat{w}_t^* . \tag{A7}$$

8.2 Log-Linearization of the entire system

8.2.1 Firm's Equations

Log-linearization of Equations (1), (2), (6), and (7) yields[21]

$$\hat{Y}_t = z + \theta \hat{K}_t + (1-\theta) \hat{H}_t , \tag{A8}$$

$$z_{t+1} = \rho_z z_t + \varepsilon_{t+1} , \tag{A9}$$

$$\begin{aligned} \hat{w}_t - \hat{p}_t = z_t + \theta \hat{K}_t - \theta \hat{H}_t - \frac{2\alpha \bar{P}}{\bar{W}} \left(\hat{H}_t - \hat{H}_{t-1} \right) \\ + \frac{2\alpha \bar{P}}{\bar{W}} \underset{t}{E} \left[\hat{H}_{t+1} - \hat{H}_t \right] \end{aligned}, \tag{A10}$$

$$\begin{aligned} \hat{r}_t - \hat{p}_t = z_t - (1-\theta) \hat{K}_t + (1-\theta) \hat{H}_t - \frac{2\alpha \bar{P}}{\bar{R}} \left(\hat{K}_t - \hat{K}_{t-1} \right) \\ + \frac{2\alpha \bar{P}}{\bar{R}} \underset{t}{E} \left[\hat{K}_{t+1} - \hat{K}_t \right] \end{aligned}. \tag{A11}$$

8.2.2 Household's Equations

Log-linearization of equations A28 – A32 is straight forward and is given by:

$$\begin{aligned} \hat{\Lambda}_t = \left((1-\sigma-\eta) B_1 + \eta - 1 \right) \hat{C}_t + (1-\sigma-\eta) B_2 \hat{m}_t \\ - (1-\sigma-\eta) B_2 \hat{p}_t - \chi (1-\sigma) \frac{\bar{H}}{1-\bar{H}} \hat{H}_t \end{aligned}, \tag{A12}$$

$$\begin{aligned} \hat{\Lambda}_{0t} &= \left((1-\sigma-\eta) B_1 + \eta - 1 \right) \hat{C}_t + (1-\sigma-\eta) B_2 \hat{m}_t \\ &\quad - (1-\sigma-\eta) B_2 \hat{p}_t - \chi (1-\sigma) \frac{\bar{H}}{1-\bar{H}} \left[\left(\frac{1}{\varphi - 1} \right) \left(w_t^* - w_t \right) + \hat{H}_t \right] \\ &= \hat{\Lambda}_t - \chi (1-\sigma) \frac{\bar{H}}{1-\bar{H}} \left[\left(\frac{1}{\lambda - 1} \right) \left(\hat{w}_t^* - \hat{w}_t \right) \right] \end{aligned}, \tag{A13}$$

[21] I transformed nominal variable to impose stationary and denote these variables by lower case letter. Upper case letters with bars denote steady state value.

$$\hat{\Lambda}_t = \frac{\beta\bar{R}}{\bar{P}} \underset{t}{E}\left[\hat{\Lambda}_{t+1} + \hat{r}_{t+1} - \hat{p}_{t+1}\right], \tag{A14}$$

$$\hat{\Lambda}_t - \hat{p}_t = \hat{Q}_t + \underset{t}{E}\left[\hat{\Lambda}_{t+1} - \hat{p}_{t+1}\right], \tag{A15}$$

$$\frac{1}{\bar{Q}-1}\hat{Q}_t = (\eta-1)\hat{m}_t - (\eta-1)\hat{C}_t - (\eta-1)\hat{p}_t, \tag{A16}$$

where, $X_1 = \bar{C}^\eta \left(\bar{C}^\eta + b\left(\frac{\bar{M}}{\bar{P}}\right)^\eta\right)^{-\eta}$ and $X_2 = 1 - X_1$.

The log-linearization of (A6) is broken down into several steps. I start by multiplying the LHS of (A6) by the denominator of the RHS of (A6) and rewrite as

$$\lambda w_t^* \frac{\Lambda_{it}}{p_t} H_t w_t^{\frac{1}{1-\lambda}} + \lambda w_t^* E_t \sum_{j=0}^{\infty} (\beta\varphi)^{j+1} \frac{\Lambda_{i,t+j+1}}{p_{t+j+1}} H_{t+j+1} w_{t+j+1}^{\frac{1}{1-\lambda}}$$

$$= \chi\left[\left(C_t^\eta + b\left(\frac{m_t}{p_t}\right)^\eta\right)^{\frac{1-\sigma}{\eta}} \left(1 - \left(\frac{w_t^*}{w_t}\right)^{\frac{1}{\lambda-1}} H_t\right)^{\chi-1-\chi\sigma} w_t^{\frac{1}{1-\sigma}} H_t\right]$$

$$+\chi\sum_{j=0}^{\infty}(\beta\varphi)^{j+1}\left[\left(C_{t+j+1}^\eta + b\left(\frac{m_{t+j+1}}{p_{t+j+1}}\right)^\eta\right)^{\frac{1-\sigma}{\eta}} \left(1 - \left(\frac{w_{t+j+1}^*}{w_{t+j+1}}\right)^{\frac{1}{\lambda-1}} H_{t+j+1}\right)^{\chi-1-\chi\sigma} \cdots w_{t+j+1}^{\frac{1}{1-\sigma}} H_{t+j+1}\right] \tag{A17}$$

Take (A17) one period forward to get

$$\lambda w_{t+1}^{*} E_t \sum_{j=0}^{\infty} (\beta\varphi)^j \frac{\Lambda_{i,t+j+1}}{p_{t+j+1}} H_{t+j+1} w_{t+j+1}^{\frac{1}{1-\lambda}}$$

$$= \chi \sum_{j=0}^{\infty} (\beta\varphi)^j \left[\left(C_{t+j+1}^{\eta} + b\left(\frac{m_{t+j+1}}{p_{t+j+1}}\right)^{\eta} \right)^{\frac{1-\sigma}{\eta}} \left(1 - \left(\frac{w_{t+j+1}^{*}}{w_{t+j+1}}\right)^{\frac{1}{\lambda-1}} H_{t+j+1} \right)^{\chi-1-\chi\sigma} \cdots \; w_{t+j+1}^{\frac{1}{1-\sigma}} H_{t+j+1} \right] \tag{A18}$$

Next, subtract (A18) from (A17) to yield

$$\lambda w_t^{*} \frac{\Lambda_{it}}{p_t} H_t w_t^{\frac{1}{1-\lambda}} - \chi \left[\left(C_t^{\eta} + b\left(\frac{m_t}{p_t}\right)^{\eta} \right)^{\frac{1-\sigma}{\eta}} \left(1 - \left(\frac{w_t^{*}}{w_t}\right)^{\frac{1}{\lambda-1}} H_t \right)^{\chi-1-\chi\sigma} w_t^{\frac{1}{1-\sigma}} H_t \right]$$
$$+ \left(w_t^{*} - w_{t+1}^{*} \right) \lambda E_t \sum_{j=0}^{\infty} (\beta\varphi)^{j+1} \frac{\Lambda_{i,t+j+1}}{p_{t+j+1}} H_{t+j+1} w_{t+j+1}^{\frac{1}{1-\lambda}} = 0 \tag{A19}$$

Now, log-linearize equation (A19) and simplify to obtain

$$\begin{aligned} &\hat{w}_t^{*} + \hat{\Lambda}_{it} - \hat{p}_t - (1-\sigma)X_1\hat{C}_t - (1-\sigma)X_2\hat{m}_t + (1-\sigma)X_2\hat{p}_t \\ &+ \frac{1}{1-\lambda}(\chi-1-\chi\sigma)\frac{\bar{H}}{1-\bar{H}}\hat{w}_t - \frac{1}{1-\lambda}(\chi-1-\chi\sigma)\frac{\bar{H}}{1-\bar{H}}\hat{w}_t^{*} \\ &+ (\chi-1-\chi\sigma)\frac{\bar{H}}{1-\bar{H}}\hat{H}_t + \frac{\beta\varphi}{1-\beta\varphi}\left(\hat{w}_t^{*} - \hat{w}_{t+1}^{*}\right) = 0 \end{aligned} \tag{A20}$$

Finally, sum over $\hat{\Lambda}_{it}$ to get

$$\begin{aligned} &\hat{w}_t^{*} + \hat{\Lambda}_t + \chi(1-\sigma)\frac{\bar{H}}{1-\bar{H}}\frac{1}{\lambda-1}\left(\hat{w}_t - \hat{w}_t^{*}\right) - \hat{p}_t - (1-\sigma)X_1\hat{C}_t \\ &-(1-\sigma)X_2\hat{m}_t + (1-\sigma)X_2\hat{p}_t + \frac{1}{1-\lambda}(\chi-1-\chi\sigma)\frac{\bar{H}}{1-\bar{H}}\hat{w}_t \\ &-\frac{1}{1-\lambda}(\chi-1-\chi\sigma)\frac{\bar{H}}{1-\bar{H}}\hat{w}_t^{*} + (\chi-1-\chi\sigma)\frac{\bar{H}}{1-\bar{H}}\hat{H}_t + \frac{\beta\varphi}{1-\beta\varphi}\left(\hat{w}_t^{*} - \hat{w}_{t+1}^{*}\right) = 0 \end{aligned} \tag{A21}$$

8.2.3 Other Equations

The log-linearization of the resource constraint gives

$$\hat{Y}_t = \frac{\overline{C}}{\overline{Y}}\hat{C}_t + \frac{\overline{K}}{\overline{Y}}\hat{K}_{t+1} - \frac{\overline{K}}{\overline{Y}}(1-\delta)\hat{K}_t \tag{A22}$$

Finally, I log-linearize the aggregate wage equation and the evolution of money supply.

$$\hat{w}_t = \varphi\hat{w}_{t-1} + (1-\varphi)\,\hat{w}_t^* \tag{A23}$$

$$\hat{m}_t - \hat{m}_{t-1} = \mu_t \tag{A24}$$

$$\mu_{t+1} = \rho_\mu \mu_t + \xi_{t+1} \tag{A25}$$

The entire system in log-deviation form is summarized by (A8)-(A14) and (A21)-(A25).

Figure 1. Impulse Response Functions of Output to a Monetary Shock

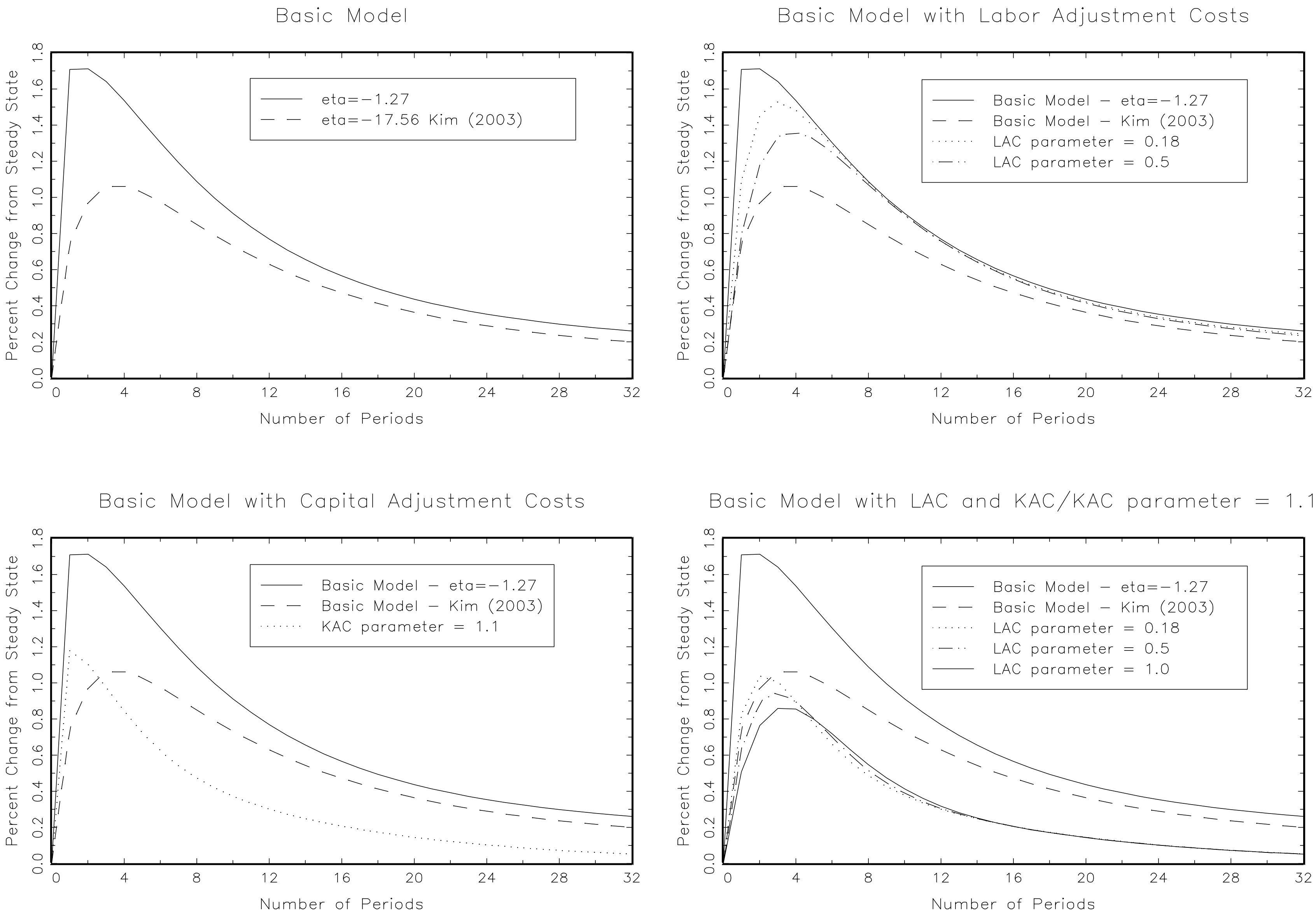

Table 2: U.S. Data and Basic Model without Adjustment Costs

	Standard Deviations				Correlations			
	H	Y	i	P	corr(Y,H)	corr(Y,Y/H)	corr(Y,i)	corr(Y, P)
U.S. Data 1954.1-1999.4	1.51	1.65	0.56	1.43	0.86	0.49	0.13	-0.52
Basic Model								
nu = -1.53	3.32	2.60	0.27	1.39	0.94	-0.42	0.83	0.46
nu = -17.56	2.00	1.83	0.34	1.39	0.88	0.07	0.64	0.14

Note:
Y = Output = real GNP; H = Hours = total hours of work; Y/H = Productivity = ouput devided by total hours;
inf = Inflation = changeLN(CPI); i =Nominal interest rate = 3-month treasury bill rate.

Table 3. Basic Model with Adjustment Costs

	Standard Deviations				Correlations			
	H	Y	i	P	corr(Y,H)	corr(Y,Y/H)	corr(Y,i)	corr(Y, P)
A: basic model with labor adjustment costs only								
alphaH = 0.18	2.87	2.31	0.23	1.68	0.92	-0.29	0.77	0.48
alphaH = 0.5	2.52	2.09	0.20	1.72	0.91	-0.18	0.71	0.47
B: basic model with capital adjustment costs only								
alphaK = 1.1	2.10	1.51	0.23	1.57	0.80	-0.14	0.45	0.14
C: basic model with both labor and capital adjustment costs								
alphaH = 0.18 and alphaK = 1.1	1.93	1.42	0.22	1.63	0.77	-0.07	0.34	0.18
alphaH = 0.5 and alphaK = 1.1	1.80	1.34	0.21	1.72	0.74	0.01	0.25	0.20