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STICKY PRICE AND LIMITED PARTICIPATION MODELS OF MONEY: A COMPARISON

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ABSTRACT

This paper provides new evidence that models of the monetary transmission mechanism should be consistent with at least the following facts. In response to a contractionary monetary policy shock, the aggregate price level responds very little, aggregate output falls, interest rates initially rise, real wages decline, though by a modest amount, and profits fall. The paper argues that neither sticky price nor limited participation models can convincingly account for these facts. The key failing of the sticky price model is that it implies profits rise after a contractionary monetary policy shock. This finding is robust to a variety of perturbations of the benchmark sticky price model that we consider. In contrast, the limited participation model can account for all of the facts mentioned above. But it can do so only if one is willing to assume a high labor supply elasticity (2) and a high average markup (40%). The shortcomings of both models reflect the absence of other frictions, such as wage contracts, which dampen movements in the marginal cost of production after a monetary policy shock.

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1. Introduction

Plausible models of the monetary transmission mechanism should be consistent with at least the following facts about the effects of a contractionary monetary policy shock:

- the aggregate price level initially responds very little,
- interest rates initially rise,
- aggregate output falls,
- real wages decline, though by a modest amount, and
- profits fall.

This paper provides new evidence to document these facts and assesses the ability of sticky price and limited participation models to account for them. Neither model succeeds. A generic failing of the sticky price model is it implies that profits *rise* after a contractionary monetary policy shock. In contrast, the limited participation model is capable of accounting for all of the above facts, but only if one is willing to assume an implausibly high labor supply elasticity (e.g. 2) and a high average markup (e.g. 40). In our view it is unlikely that any model which allows for only one type of friction will able to account for all of the facts in a plausible way. But our results suggest that limited participation models are a more useful starting point than sticky price models.

To assess the effects of an exogenous shock to monetary policy, we use close variants of the policy shock measures developed in Christiano, Eichenbaum and Evans (1996) and Sims and Zha (1995). Since the first three facts mentioned above have been extensively documented in the literature, we focus the bulk of our empirical analysis on real wages and profits. Using both aggregate and sectoral data, we show that a contractionary monetary policy shock is associated with a small decline in real wages and a sharp, persistent drop in profits.

Based on our empirical analysis, we take as given the five facts listed above. We then turn to the question: What type of frictions are likely to be helpful in accounting for these facts? The first fact leads us to dismiss the Lucas (1972) model of money from consideration. This is because the engine driving the signalling problem at the core of that model is a rapid movement in the price level after a monetary policy shock. Such price movements are not observed in the post-war US data. The fourth fact leads us to dismiss simple sticky wage models from consideration. This is because those types of models imply that real wages rise, not fall, after a contractionary monetary policy shock.

In light of these considerations, we concentrate on two frictions that have received substantial attention in the recent literature. The first is that some firms do not immediately adjust prices in response to monetary policy shocks. With output being demand determined, the effect of this friction is that aggregate output falls in response to a monetary contraction. The second friction is that households do not immediately adjust their money holdings in response to monetary policy shocks. The effect of this friction is that monetary contractions disproportionately affect the reserves of banks and, hence, the supply of loanable funds. The resulting rise in interest rates induces firms who need working capital to cut back on their scale of operations, and aggregate output declines.

While these two frictions are by no means mutually exclusive, we find it useful to initially analyze them in isolation. We do this by considering separately, the consequences of introducing them into a single, benchmark model.[1] The model economy is populated by an infinitely lived representative agent, a monetary authority, a competitive producer of final goods and a continuum of intermediate good producers, each of whom are monopolists. In addition, there is a financial intermediary, which intermediates cash loans from households to intermediate good firms. The household purchases the final consumption good, supplies labor to intermediate good firms and lends funds to the financial intermediary. The financial intermediary combines funds received from households with lump-sum injections of money from the government and makes loans to intermediate good firms. These firms need loans because they must pay labor before they sell their output. The size of the money transfers from the monetary authority to the financial intermediary is the only source of uncertainty in the model economy.

In the *sticky price* version of the model, the sequence of events within a period is as follows. First, intermediate good producers set their prices. Then the current period money

[1] Our benchmark model economy is closely related to the one considered by Blanchard and Kiyotaki (1987), Chari, Christiano and Eichenbaum (1995), Chari, Kehoe and McGrattan (1996), Cho and Cooley (1995), Ireland (1995), King and Watson (1996), Ohanian, Stockman and Kilian (1996) and Woodford (1996).

growth rate is realized. Finally, all other model variables are realized, with the output of the intermediate goods producers being demand determined. In the *limited participation* version of the model, goods prices are flexible but we incorporate the second type of monetary friction discussed above. As in Lucas (1990), Christiano (1991), Fuerst (1992) and Christiano and Eichenbaum (1992, 1994, 1995), we do this by assuming that, in any given period, households must determine how much money to deposit with financial intermediaries prior to the realization of the money shock.

We analyze how the model economies respond to an exogenous shock in the growth rate of money. Our findings can be summarized as follows. The key failing of the sticky price model is that it implies profits rise after a monetary contraction. This is true across a broad set of parameter values and perturbations of the model. The intuition is quite simple. With output being demand determined, a monetary contraction leads to a substantial decline in employment. Absent labor market frictions, or an extremely high elasticity of labor supply, this leads to a substantial fall in wages and marginal costs, along with a sharp rise in the markup. Although revenues fall, the cost considerations dominate and profits rise. We conclude that sticky prices alone are not sufficient to account for the key facts. In our view, labor market frictions, whose effect is to inhibit cyclical movements in marginal costs by mimicking very high labor supply elasticities, need to be embedded in the current generation of general equilibrium sticky price models.[2]

We reach the same conclusion with the limited participation model, but the path by which we reach it is different. The limited participation model does at least as well, if not better, than the sticky price model. For this model we find that *if* one is willing to assume a reasonably high markup (e.g., 40 percent) and a high labor supply elasticity (e.g., 2 percent), then the limited participation model can account for all of the stylized facts stressed above. Specifically, a contractionary shock to the growth rate of money has essentially no contemporaneous impact on the price level, and drives wages, profits, output and employment down, while driving the rate of interest up. But if one is not willing to accept high markups and labor supply elasticities, then the model has difficulty in generating a large output effect

[2]Romer (1996) adopts a different but related approach to argue that sticky price models require real labor market frictions to generate large output effects from a monetary policy shock.

and a small price effect from a monetary policy shock. As with the sticky price models, it seems important to embed labor market frictions whose effect is to mimic a high elasticity of labor supply into the current generation of limited participation models. We conclude that general equilibrium models which allow for *only* one type of friction cannot convincingly account for the salient facts about how the economy responds to an unanticipated monetary policy shock.

The previous remarks may seem to suggest that requiring a subset of the intermediate good firms in the limited participation model to set their price in advance could remedy the shortcomings of that model. However, we find that this change has only a relatively small impact on the equilibrium price and output response to a monetary policy shock. This is true even when as many as 80% of the intermediate good firms set their price in advance. The basic reason is as follows. For the subset of the firms who set prices in advance, the output effect of a contractionary policy shock is greater than in the equilibrium when everyone sets prices flexibly. But the large drop in employment of labor and capital by fixed price firms leads to a large drop in the marginal cost of production. This in turn leads flexible price firms to drop their prices by a large amount and to actually *increase* output. This effect, which operates through the general equilibrium impact of a monetary shock on marginal costs, accounts for the small impact on aggregate price and output dynamics of introducing price setters. This basic result holds even if there is limited mobility of capital and labor between the fixed and sticky price sectors of the economy. We conclude that embedding labor market frictions in the limited participation model is likely to prove a more fruitful way of remedying its shortcomings than allowing for sticky prices.

The finding that flexible price setters adjust their prices by more, the larger is the fraction of firms which fix prices in advance, also holds in a version of the sticky price model in which only a fraction of the firms set prices in advance. In our view, this finding calls into question the basic appeal of the sticky price model. Presumably, the appeal of that model rests on the notion that flexible price firms act more like fixed price firms the larger is the fraction of the firms in the economy who set their price in advance. But at least for the environments that we consider, the opposite is true.[3]

The remainder of this paper is organized as follows. Section 2 reviews the policy shocks used in our empirical analysis and presents our empirical results. In section 3 we present the theoretical models. Sections 4 and 5 discuss qualitative and quantitative properties of the models, respectively. Concluding remarks appear in Section 6.

2. Some Facts About the Empirical Effects of Monetary Policy Shocks

2.1. Policy Shock Measures

In our empirical analysis we use two measures of shocks to monetary policy. These are close variants of measures developed in Christiano, Eichenbaum and Evans (1996) (CEE) and Sims and Zha (1995) (SZ). Both procedures posit that the Fed follows an interest rate targeting rule, and that the monetary policy shock is a disturbance to that rule. They differ on the assumptions made to identify that shock.

CEE Policy Shocks

CEE identify a monetary policy shock with the disturbance term in the following interest rate targeting rule:

$$R_t = \psi(\Omega_t) + \varepsilon_{st}, \tag{2.1}$$

where R_t is the Federal Funds Rate, ψ is a linear function, Ω_t summarizes the information set that the monetary authority looks at when setting R_t and ε_{st} is a serially uncorrelated shock that is orthogonal to the elements of Ω_t. (CEE also work with a version of (2.1) where R_t is replaced by a measure of the nonborrowed reserves of banks.) The orthogonality

[3]These considerations suggest changing our environment to allow for factors which increase complementarity among price setters. This could, for example, be achieved by assuming that intermediate good producers use the output of other intermediary goods producers as inputs to production (see Basu (1995).) It would be of interest to explore the implications of this model modification in our environment. However, experiments reported in Chari, Kehoe and McGrattan (1996), suggest that the gains from this modification may not be large.

restriction on ε_{st} corresponds to a particular recursiveness assumption: the monetary policy variable, R_t, is contemporaneously affected by the date t variables in Ω_t, but those variables are not contemporaneously affected by the monetary policy shock. The advantage of this recursiveness assumption is that it justifies estimating ε_{st} as the residual in an ordinary least squares regression of R_t on Ω_t. The impulse response of a variable to a policy shock can be measured by the coefficients in the regression of the variable on current and lagged values of the fitted residuals in (2.1).

In practice, we estimate the impulse response functions by an asymptotically equivalent procedure based on a Vector Autoregressive Representation (VAR) for a vector of variables, Z_t. For the details of this procedure, see *CEE*. In our benchmark VAR, Z_t includes the log of real GDP, the log of the GDP deflator, an index of the change in sensitive commodity prices, the federal funds rate, the log of nonborrowed reserves, the log of total reserves, and the log first difference of $M2$. We structure the VAR so that is captures the *CEE* recursiveness assumption, and specifies that the contemporaneous variables in Ω_t are the first three variables in Z_t. The rationale for this specification is discussed in *CEE.* To assess the effect of a monetary policy shock on real wages we added the log of real wages to Z_t. To assess the effect of a policy shock on the share of profits in output, we added the ratio of profits to nominal GNP to Z_t. We exclude contemporaneous real wages and the ratio of profits to nominal GNP from Ω. The estimation period is 1965Q3-1995Q2, and the VAR's have lag length 4. We refer the reader to appendix A for a detailed description of the data.

Sims - Zha Policy Shocks

Although the recursiveness assumption implicit in the *CEE* procedure buys considerable simplicity, it may come at the cost of specification error. For this reason, we also consider *SZ*, whose strength is that it does not make the recursiveness assumption. The cost, however, is that *SZ* must identify a broader set of economic relationships than do *CEE*. Their identification assumptions could also entail specification error. For example, *SZ* assume that contemporaneous output does not enter the monetary policy rule, but it does enter the money demand equation. (See Appendix B for further details.)

SZ assume a monetary policy rule of the form

$$R_t = g(\Theta_t) + \varepsilon_{st}. \tag{2.2}$$

Here g is a linear function and Θ_t summarizes the variables that the policymakers looks at when setting the target interest rate, R_t. SZ identify R_t with the 3 - month rate of return on Treasury bills. The information set, Θ_t, is composed of time t values of crude materials prices and $M2$, and lagged values of the Treasury bill rate, intermediate materials prices, the aggregate price level, real wages, aggregate output, crude materials prices, $M2$, and a measure of personal bankruptcies.

Under SZ's assumptions, all of the variables in Z_t can respond contemporaneously to a monetary policy shock. Because the monetary policy shock is not orthogonal to the elements of Θ_t, it cannot be identified with the residuals in a least squares regression of R_t on the elements of Θ_t. The exact SZ procedure for identifying the policy shock is summarized in Appendix B. The associated impulse response functions are estimated using standard VAR methods. As in SZ, our VAR has four lags, and the estimation period is the same as for the CEE system.

Our version of SZ does not include their measure of personal bankruptcies, since we did not have access to this data. In addition we worked with the first difference of log $M2$. We did this to facilitate comparisons with the CEE results. In addition we do not impose the over identifying restrictions used by SZ that the demand for real balances has a coefficient of one on contemporaneous real income.[4] To assess the effect of a monetary policy shock on the ratio of profits to nominal GNP we amended the SZ system in a way that is summarized in Appendix B.

[4]Comparing the estimated dynamic response functions to a monetary shock in our benchmark system with those in SZ, it can be verified that these three perturbations make very little difference to the results.

2.2. The Effects of Monetary Policy Shocks on Wages and Profits

In this section we report the effects of a contractionary monetary policy shock on real wages and corporate profits. To help assess the properties of our benchmark policy shock measures, Figure 1 displays the effects of contractionary benchmark CEE and SZ policy shocks on various economic aggregates. Solid lines report point estimates of dynamic response functions. Dashed lines denote a 95% confidence interval for the dynamic response functions.[5] Since close variants of these response functions are discussed in Christiano, Eichenbaum and Evans (1996) and Sims and Zha (1995), we comment on them only briefly here.

The main consequences of a contractionary benchmark CEE policy shock can be summarized as follows. First, there is a persistent rise in the federal funds rate and a persistent drop in nonborrowed reserves and in the growth rate of $M2$. After a one quarter delay, the shock also leads to a persistent decline in total reserves. Second, after a delay of 2 quarters, there is a sustained decline in real GDP.[6] Third, after an initial delay, the policy shock generates a persistent decline in the index of commodity prices. The GDP deflator is flat for roughly a year and a half after which it declines. Fourth, we cannot reject the hypothesis that a monetary policy shock has no effect on real balances in the long run.

[5]The 95 percent confidence intervals for the CEE impulse response functions were computed using the following bootstrap Monte Carlo procedure. We first constructed 1000 time series on the vector Z_t, each of length T, where T denotes the number of observations in our data sample. Let $\{\widehat{u}_t\}_{t=1}^T$ denote the vector of residuals from the estimated VAR. We constructed 1,000 sets of new time series of residuals, $\{\widehat{u}_t(j)\}_{t=1}^T$, $j = 1, ..., 1000$. The t^{th} element of $\{\widehat{u}_t(j)\}_{t=1}^T$ was selected by drawing randomly, with replacement, from the set of fitted residual vectors, $\{\widehat{u}_t\}_{t=1}^T$. For each $\{\widehat{u}_t(j)\}_{t=1}^T$, we constructed a synthetic time series of Z_t, denoted $\{Z_t(j)\}_{t=1}^T$, using the estimated VAR and the historical initial conditions on Z_t. Second, we re-estimated our VAR using $\{Z_t(j)\}_{t=1}^T$ and the historical initial conditions, and calculated the implied impulse response functions for $j = 1, ..., 1000$. For each fixed lag, we calculated the 25^{th} lowest and 975^{th} highest value of the corresponding impulse response coefficient across all 1000 synthetic impulse response functions. The boundaries of the confidence intervals in the figures correspond to a graph of these coefficients. The solid line reports our point estimate of the impulse response function. For the most part, these point estimates are quite similar to the mean value of the simulated impulse response functions. There is some evidence of bias, especially in Figure 7, which displays results for our aggregate measures of profits. Interestingly, the evidence of bias suggests that our point estimates understate the magnitude of the drop in profits after a monetary contraction.

The bands for the SZ impulse response functions were computed using the procedure described in Sims and Zha (1995a). The reported bands are two standard deviations about the mean of the impulses. As in the case CEE, the solid line reports our point estimate of the impulse response function.

[6]The asymmetry in the confidence bands suggests that our estimate of the response of GDP to a monetary policy shock is biased towards zero. Thus a bias-adjusted estimator would indicate a stronger negative response of GDP to a contractionary monetary policy shock. The same is true for the response of aggregate profits to a monetary policy shock (see Figure 7).

The main consequences of a contractionary benchmark SZ policy shock can be summarized as follows. First, there is a persistent decline in the growth rate of $M2$ and a rise in the interest rate. Second, there is a persistent decline in the GDP deflator as well as the prices of intermediate goods and crude materials. Third, after a delay, the shock generates a persistent decline in real GDP. Finally, note that the benchmark measure of real wages (average hourly earnings of private nonagricultural production workers divided by the GDP deflator) is basically unaffected by the SZ policy shock. Overall, the qualitative response of the system to a policy shock is quite similar for the CEE and SZ policy shocks measures. However, the estimated SZ policy shocks are somewhat smaller than the estimated CEE policy shocks. For example the impact effect of a CEE policy shock on the federal funds rate is about 70 basis points, while the impact of a SZ policy shock on the 3 month Treasury bill rate is about 40 basis points. In addition, the impulse response functions associated with the SZ policy shocks are estimated somewhat less precisely than the ones associated with the CEE policy shocks.

Figure 2 reports the response of different measures of real wages to contractionary CEE and SZ policy shocks. Rows 1 through 6 report the response of five measures of aggregate real wages: (1) the benchmark measure discussed above, (2) average hourly earnings of production workers in the private nonagricultural sector deflated by the Bureau of Labor Statistics using an index derived from the Consumer Price Index for Urban Wage Earners and Clerical Workers, (3) average hourly earnings of production workers in the manufacturing sector divided by the GDP deflator, (4) average hourly earnings of production workers in the manufacturing durable goods sector divided by the GDP deflator, and (5) average hourly earnings of production workers in the manufacturing nondurable goods sector divided by the GDP deflator.

The key results can be summarized as follows. First, with two exceptions, regardless of which policy shock or which measure of real wages we work with, according to the point estimates, a contractionary monetary policy shock leads to a persistent decline in the real wage. The exceptions are that measures (1) and (5) of the real wage appear roughly unaffected by a SZ policy shock. Second, for both policy shock measures, manufacturing real wages fall more sharply than economy wide wage measures. Finally, within manufacturing, real wages fall more sharply in the durable good industries than in the nondurable good industries. Generally speaking, the decline in real wages following a SZ policy shock are smaller and less precisely estimated than those following a CEE policy shock.

Next we consider the response of real wages at the 2 digit SIC industry level to a contractionary policy shock. Throughout wages are measured as gross average hourly earnings of production and nonsupervisory workers deflated by the GDP deflator. Figure 3 reports the response of real wages to a contractionary CEE policy shock for ten 2 digit nondurable SIC code industries.[7] Figure 4 reports the analog results for a SZ policy shock. Figure 5 reports the response of real wages to a contractionary CEE policy shock for ten 2 digit SIC code durable good industries.[8] Figure 6 reports the analog results for a SZ policy shock.

The key results can be summarized as follows. First, real wages in all but one of the nondurable and durable good industries (leather and leather products, and instruments and related products, respectively) fall after a contractionary CEE policy shock. Second, the declines are greater in the durable goods industries than in the nondurable good industries. Third, for both industries, the results are more mixed for the SZ policy shock measure.

Integrating across all of our results, we conclude there is substantial evidence in support of the view that real wages fall in response to a contractionary monetary policy shock. There is certainly no evidence to support the view that real wages rise in response to such a shock.

We now discuss the response of profits to a monetary policy shock. Figure 7 reports the response of seven different measures of profits to contractionary CEE and SZ policy shocks: (1) total before tax profits, (2) total after tax profits, (3) net domestic profits after taxes, (4) nonfinancial net domestic after tax profits, (5) total after tax profits net of interest costs, (6) net after tax domestic profits net of interest costs, and (7) nonfinancial after tax domestic profits net of interest costs. The last three measures of profits are of some interest because they allow us to isolate the role that interest rate costs play in the response of profits to a

[7]Food and Kindred Products SIC 20, Tobacco SIC 21, Textile Mill Products SIC 22, Apparel and Other Textiles SIC 23, Paper and Allied Products SIC 26. Printing and Publishing SIC 27, Chemicals and Allied Products SIC 28, Petroleum and Coal SIC 29, Rubber and Miscellaneous Plastic Products SIC 30 and Leather and Leather Products SIC 31.

[8]Lumber and Wood Products SIC 24, Furniture and Fixtures SIC 25, Stone, Clay and Glass SIC 32, Primary Metal Industries SIC 33, Fabricated Metal Industries SIC 34, Machinery - Except Electrical SIC 35, Electric and Electronic Equipment, SIC 36, Transportation Equipment SIC 37, Instruments and Related Products SIC 38 and Miscellaneous Manufacturing SIC 39.

contractionary policy shock. Notice that, regardless of which measure we work with, a both CEE and SZ contractionary monetary policy shocks lead to a persistent decline in profits. This is true even when we construct profits in a way that does not take into account interest costs. The dynamic impulse response functions are estimated less precisely than in the CEE case.

Next we consider the response of profits at the sectoral level to contractionary CEE and SZ policy shocks. Figure 8 reports the response of before tax profits in five sectors of the economy: manufacturing, nondurables, durables, retail, and transportation and utilities. As above, profits are calculated as a fraction of nominal GDP. Notice that for the CEE policy shock measures, profits in manufacturing, durable goods and the retail sector experience persistent drops after a contractionary policy shock. This is not true for nondurable goods and transportation and utilities. While profits appear to rise in these industries, one cannot reject the hypothesis that profits are unaffected by the policy shock. The results with the SZ policy shock measures are consistent with those of the CEE policy shock measures, although again the dynamic response functions are estimated less precisely. Integrating over figures 7 and 8, there is strong evidence that profits fall after a contractionary policy shock.

Based on the evidence reported in this section, we conclude that business cycle models ought to have the implication that output, real wages and profits fall in response to a contractionary policy shock. The aggregate price level should not respond, at least for a substantial period of time. While there is uncertainty about the response of real wages, plausible theories will not have the implication that real wages rise after a contractionary policy shock.

3. Our Sticky Price and Limited Participation Models

In this section we describe our fixed price and limited participation models, which correspond to two specifications of the sequence of events in a basic, benchmark model. We first present the problems faced by the agents in our model, and we then discuss our equilibrium concept.

3.1. Final Goods Firms

At time t, a final consumption good, Y_t, is produced by a perfectly competitive firm. It does so by combining a continuum of intermediate goods, indexed by $i \in (0,1)$, using the technology:

$$Y_t = \left[\int_0^1 Y_{it}^{\frac{1}{\mu}} di\right]^{\mu}, \tag{3.1}$$

where $1 \leq \mu < \infty$ and Y_{it} denotes the time t input of intermediate good i. Let P_t and P_{it} denote the time t price of the consumption good and intermediate good i, respectively. Profit maximization implies the Euler equation:

$$\left(\frac{P_t}{P_{it}}\right)^{\frac{\mu}{\mu-1}} = \frac{Y_{it}}{Y_t}. \tag{3.2}$$

According to (3.2), the demand for intermediate good i is a decreasing function of the relative price of that good, and an increasing function of aggregate output, Y_t. Integrating (3.2) and imposing (3.1), we obtain the following relationship between the price of the final good and the price of the intermediate goods:

$$P_t = \left[\int_0^1 P_{it}^{\frac{1}{1-\mu}} di\right]^{(1-\mu)}. \tag{3.3}$$

3.2. Intermediate Good Firms

Intermediate good i is produced by a monopolist who uses the following technology:

$$Y_{it} = \begin{cases} K_{it}^{\alpha} N_{it}^{1-\alpha} - \phi & \text{if } K_{it}^{\alpha} N_{it}^{1-\alpha} \geq \phi \\ 0 & \text{otherwise} \end{cases}, \tag{3.4}$$

where $0 < \alpha < 1$. Here, N_{it} and K_{it} denote time t labor and capital used to produce the i^{th} intermediate good. The parameter ϕ denotes a fixed cost of production. We rule out entry and exit into the production of intermediate good i.

Intermediate firms rent capital and labor in perfectly competitive factor markets. Economic profits are distributed to the firms' owner, the representative household, at the beginning of time period $t+1$. We denote the time t rental rate on capital and the wage rate by r_t and W_t, respectively. Workers must be paid in advance of production. As a result, firms need to borrow their wage bill, $W_t N_{it}$, from the financial intermediary at the beginning of the period. Repayment occurs at the end of time period t, at the gross interest rate, R_t. Consequently, the firm's total time t costs are given by $R_t W_t N_{it} + r_t K_{it}$. Their cost function is given by

$$C(r_t, R_t W_t, Y_{it}) = A(r_t)^{\alpha}(W_t R_t)^{1-\alpha}(Y_{it} + \phi), \tag{3.5}$$

where $A = \left(\frac{1}{1-\alpha}\right)^{(1-\alpha)}\left(\frac{1}{\alpha}\right)^{\alpha}$, so that the time t marginal cost of producing additional output, given $Y_{it} > 0$, is $MC(r_t, R_t W_t) = A r_t^{\alpha}(W_t R_t)^{1-\alpha}$. A convenient representation of this expression, which holds in equilibrium, is given by:

$$MC(r_t, R_t W_t) = \frac{1}{1-\alpha} N_t^{\alpha} W_t R_t, \tag{3.6}$$

where N_t denotes aggregate employment, and we have taken into account our assumption that the aggregate stock of capital is a constant, unity.[9]

In the version of the model where prices are set flexibly, profit maximization leads the intermediate good firm to set its price equal to a constant markup over marginal cost:

$$P_{it} = \mu MC_t. \tag{3.7}$$

In the version of the model where the firm sets its price prior to the realization of the money shock, it does so to optimize the appropriately weighted expectation of profits:

$$E_{t-1}\frac{U_{c,t+1}}{P_{t+1}}\left[P_{it}Y_{it} - C(r_t, R_t W_t, Y_{it})\right], \tag{3.8}$$

[9]This expression is obtained by noting that an efficiency condition of firm $i \in (0,1)$ is $r_t/(W_t R_t) = [\alpha/(1-\alpha)]\, N_{it}/K_{it}$. The implied equality of firm labor-capital ratios implies that this expression holds for the aggregate ratio of labor to capital, N_t/K_t. To obtain (3.6), we substituted this expression with the aggregate variables into $A r_t^{\alpha}(W_t R_t)^{1-\alpha}$ and took into account $K_t = 1$.

subject to the demand equation, (3.2). Here, $U_{c,t+1}$ denotes the time $t+1$ marginal utility of the representative household. The i^{th} monopoly firm takes prices and quantities other than P_{it} and Y_{it} as given and beyond its control. The weights on profits in (3.8) correspond to the marginal utility of a dollar to the firm's owner, the household, and the dating reflects our assumption - displayed below - that the household cannot spend its date t profits until date $t+1$. Under these circumstances, the firm is led to set its price equal to a constant markup over a weighted expectation of marginal cost:

$$P_{it} = \mu E_{t-1} \omega_t MC_t, \tag{3.9}$$

where

$$\omega_t = \frac{\left[E_t \frac{U_{c,t+1}}{P_{t+1}}\right] P_t^{\frac{\mu}{\mu-1}} Y_t}{E_{t-1}\left[\frac{U_{c,t+1}}{P_{t+1}} P_t^{\frac{\mu}{\mu-1}} Y_t\right]}. \tag{3.10}$$

As (3.10) makes clear, in setting its price, the firm places large weight on MC_t in states of the world where aggregate demand, Y_t, is large.

Expressions (3.2), (3.7), (3.9) indicate that in equilibrium, $N_{it} = N_t$, $K_{it} = K_t$, $Y_{it} = Y_t$ and $P_{it} = P_t$ for $i \in (0,1)$. Note that although final goods are priced flexibly, in equilibrium they inherit whatever inflexibility there is in intermediate goods prices (see (3.3)).

3.3. Financial Intermediary

At time t, a perfectly competitive financial intermediary receives deposits, I_t, from the household, and lump sum cash injections, X_t, from the monetary authority. These funds are supplied to the loan market at the gross interest rate R_t. Demand in the loan market comes from the intermediary good producers, who seek to finance their wage bill, $W_t N_t$. Clearing in the loan market requires:

$$W_t N_t = I_t + X_t. \tag{3.11}$$

At the end of the period the intermediary pays $R_t I_t$ to households in return for their deposits, and distributes $R_t X_t$ to households in the form of profits.

3.4. Household

At time t the household ranks alternative streams of consumption and hours worked according to the criterion function:

$$E_t \sum_{j=0}^{\infty} \beta^j U(C_{t+j}, N_{t+j}). \tag{3.12}$$

Here $0 < \beta < 1$, C_t denotes time t units of consumption, N_t denotes time t hours of work and

$$U(C, N) = log \left[C - \frac{\psi_0}{1+\psi} N^{1+\psi} \right]. \tag{3.13}$$

In (3.13), $\psi_0 > 0$ and $\psi > 0$. Specification (3.13) has the convenient feature that the household has a well-defined static labor supply function, whose elasticity, $1/\psi$, is a constant.[10] In our quantitative analysis, we also consider an alternative specification of utility.

The household is endowed with K_t units of capital which it supplies inelastically to a competitive rental market, in which the rental rate is denoted by r_t. To simplify the analysis, we assume there exists no technology for increasing the aggregate stock of capital, and that the rate of depreciation is zero. As a result, the per capita stock of capital is a constant, and we specify this to be unity. We assume there is no market in which agents can trade ownership claims on capital. This is without loss of generality, since we assume all agents are identical.

The household supplies N_t units of labor at the nominal wage rate W_t and faces the

[10] An argument in King, Plosser and Rebelo (1988) appears suggest that (3.13) may be difficult to reconcile with balanced growth. We can reconcile our model with balanced growth as follows. First, we think of (3.13) as the indirect utility function for a household whose actual utility function is:

$$\log (C + C_n) - \gamma \log \left(\frac{N^{1+\psi}}{1+\psi} + N_n \right),$$

where N_n and C_n denote nonmarket hours worked and consumption, respectively. Second, suppose the home production function is $C_n = \psi_0 N_n$. Proceeding as in Benhabib, Rogerson and Wright (1991), it is straightforward to show that the indirect utility function in C and N is

$$\log \left(\frac{1}{1-\gamma} \right) - \gamma \log \left(\frac{\gamma}{\psi_0 (1-\gamma)} \right) + (1-\gamma) \log \left(C - \psi_0 \frac{N^{1+\psi}}{1+\psi} \right).$$

We get a balanced growth path in which labor does not grow and all other quantities grow at a positive rate by assuming that intermediate good firm technologies and the home production function shift up at the same, constant rate.

following cash constraint on its consumption purchases:

$$P_t C_t \leq W_t N_t + M_t - I_t. \tag{3.14}$$

Here M_t denotes the household's beginning of period t holdings of cash and I_t denotes time t dollars sent to the financial intermediary. Constraint (3.14) implies that time period t wage earnings are payable to the household in time to satisfy its time t cash constraint. The household's money holdings evolve according to

$$M_{t+1} = [W_t N_t + M_t - I_t - P_t C_t] + r_t K_t + R_t [I_t + X_t] + D_t \tag{3.15}$$

where D_t and $R_t X_t$ denote time t profits received from intermediate goods producers and financial intermediaries, respectively.

The household maximizes (3.12) subject to (3.13) - (3.15). In both versions of the model, C_t, N_t, and M_{t+1} are chosen after the realization of the time t monetary shock. This is also true for I_t in the fixed price model. In the limited participation version of the model, I_t is set before the realization of the period t monetary shock.

The first order necessary condition associated with the household's choice of N_t is given by:

$$\frac{W_t}{P_t} = \psi_0 N_t^{\psi}. \tag{3.16}$$

In the sticky price version of the model, the Euler equation for I_t is given by:

$$\frac{U_{c,t}}{P_t} = R_t E_t \frac{\beta U_{c,t+1}}{P_{t+1}}. \tag{3.17}$$

According to (3.17), the household equates the marginal utility of a dollar deposited with the financial intermediary at time t to the time $t+1$ expected marginal utility of the returns from that deposit. In the limited participation version of the model, the Euler equation for

I_t is given by

$$E_{t-1}\frac{U_{c,t}}{P_t} = E_{t-1}R_t\frac{\beta U_{c,t+1}}{P_{t+1}}. \tag{3.18}$$

3.5. Monetary Authority

We assume that the growth rate of money, $x_t \equiv X_t/M_t = (M_{t+1} - M_t)/M_t$, is the realization of an exogenous, three-state Markov chain with an unconditional mean growth rate of μ_x. We discuss the details of this process in the next subsection. There, we also discuss the relationship between the representation of monetary policy used in the model, and the interest rate-targetting representation adopted in our empirical analysis.

3.6. Equilibrium and Computation

Let Z_t denote the vector of nominal variables (excluding R_t), scaled by the beginning of period stock of money. Let Q_t denote the other variables. Thus,

$$Z_t = [P_{it}, P_t, W_t, r_t, I_t]/M_t,\;\; Q_t = [R_t, C_t, Y_t, Y_{it}, K_{it}, K_t, N_t, N_{it},],\;\; i \in (0,1).$$

To define equilibrium we find it convenient to adopt a notation that allows us to be more precise about the price and commodity space. Let s^t denote the history of exogenous shocks up to time t. A sequence-of-markets equilibrium is a set of history-contingent sequences, $Z(s^t)$ and $Q(s^t)$, with the properties: (i) given the prices, the quantities solve the household and final good firm problems for each possible s^t; (ii) given the final good and factor prices, the i^{th} intermediary good price, output and inputs solve the intermediary firm problem for each $i \in (0,1)$ for each possible s^t; and (iii) the loan market clearing condition, (3.11), and the resource constraints are satisfied, $C(s^t) = Y(s^t)$ and $\int_0^1 K_i(s^t)di = K(s^t) = 1$, $\int_0^1 N_i(s^t)di = N(s^t)$ all s^t, all t. Part (iii) of our definition of equilibrium incorporates our assumption that the per capita stock of capital is unity at each date. We confine ourselves to symmetric equilibria, in which $P_i(s^t) = P(s^t)$, $Y(s^t) = Y_i(s^t)$, $K_i(s^t) = 1$ and $N_i(s^t) = N(s^t)$, for all i.

To describe how we compute equilibrium, define the state variables, $s = (x_{-1}, x)$. Under our assumptions on the money growth process, s can take on 9 possible values. Any set of nine Z_s and Q_s's induces sequences, $\{Z(s^t),\ Q(s^t);\ \text{all } s^t\}$. We compute Z_s and Q_s's such that the implied price and quantity sequences are a competitive equilibrium. In the sticky price model, P/M is restricted to vary with x_{-1} only. In the limited participation model, I/M is restricted to be a function of x_{-1} only. The Z_s and Q_s's are computed as the solution to a particular set of nonlinear equations: the first order conditions and resource constraints for each possible s.

4. Qualitative Properties of the Sticky Price and Limited Participation Models

This section discusses the qualitative properties of our models. We begin by comparing the nature of the output response to a money shock in the two models. We then discuss the interest rate and profit response to a monetary shock in the limited participation model. In analyzing this response, we pay particular attention to the role played by the magnitude of the labor supply elasticity and the markup.

4.1. The Output Effects of a Money Shock in the Two Models

Combine (3.11) (evaluated at equality) and (3.14) to obtain:

$$P_t C_t = M_t + X_t. \tag{4.1}$$

This equation must hold for interior equilibria of both versions of the model. Relation (4.1) defines a parabola in a graph with P_t on the vertical axis and C_t (or, output, Y_t, since the two are the same in our model) on the horizontal axis. This curve is depicted by the downward-sloped line labelled DD in Graph 1. The curve DD shifts to the right for higher values of X_t, just as the aggregate demand equation in an intermediate macroeconomics text book does. In the sticky price model, equilibrium output (Y) can be thought of as the intersection of the curve DD, and another curve, which is horizontal at the pre-determined price level. In Graph

1, this horizontal curve is labelled SS. As in the standard intermediate textbook treatment, the sticky price model depicts the economy's response to a money injection as a move along a fixed and horizontal short run aggregate supply curve.[11] So for a money injection given by X_t, equilibrium output is given by Y_t. The curve $D'D'$ graphs the relationship $P_t = \frac{M_t+X_t'}{Y_t}$ for $X_t' > X_t$. The equilibrium level of output that obtains for this larger money injection, Y', is given by the intersection of $D'D'$ with SS.

The limited participation model takes a very different position on the short run supply curve. One way to think of this model is that its short run supply curve, labeled SS in Graph 2, is vertical and shifts right with a money injection. A monetary injection operates like a technology shock: it reduces production costs by driving down the equilibrium rate of interest. The vertical curve $S'S'$ corresponds to the vertical supply curve that obtains for $X_t' > X_t$. If the supply side effect associated with the monetary shock is sufficiently large, then the equilibrium contemporaneous price response to the money injection could be zero or even negative.

To understand the supply side effect of a monetary policy shock in the limited participation model, it is useful to understand its impact on the labor market. Relations (3.6) and (3.7) imply that, in equilibrium, labor demand is given by

$$\frac{W_t}{P_t} = \frac{(1-\alpha)N_t^{-\alpha}}{\mu R_t}. \tag{4.2}$$

Relation (4.2) can be expressed as a labor demand schedule in real wage - employment space. This schedule is depicted by the downward-sloped line in Graph 3 labeled DD. Other things equal, a decrease in the interest rate shifts the labor demand curve to the right. These effects occur because the firm equates the value of labor's marginal product to a markup over the cost of hiring labor, inclusive of financing costs.

Relation (3.16), the household Euler equation for N_t, defines a static upward-sloped labor supply schedule. This schedule is depicted by the upward-sloped solid line in Graph 3 labeled

[11] Below, we also consider a version of the sticky price model in which not all firms set prices in advance. In this version of the model, the short run aggregate supply curve is, in effect, positively sloped. This change does not affect the comments we make here.

SS. For a given level of R_t, equilibrium employment is given by the intersection of the static labor demand and supply schedules. A lower value of the interest rate, $R' < R$, is associated with a rightward shift in the labor demand schedule (to the curve labeled $D'D'$) and an increase in the real wage and employment. This induces a rightward shift in the aggregate supply curve in the price level - output plane.

4.2. The Output, Interest Rate and Profit Effects of a Monetary Policy Shock in the Limited Participation Model

An important shortcoming of the previous intuition about the limited participation model is that it is based on an exogenous shift in the interest rate. In fact, the rate of interest is jointly determined with employment and output. To obtain intuition about the general equilibrium effects of a monetary shock, it is useful to consider a simplified version of the model in which $\phi = 0$.

Taking the ratio of the labor market clearing condition, (3.11), to the cash equation, (4.1):

$$\frac{W_t}{P_t}\frac{N_t}{C_t} = \Gamma_t,\ \Gamma_t = \frac{I_t + X_t}{M_t + X_t}. \tag{4.3}$$

The variable, Γ_t, is the ratio of funds passing through the loan market, to funds passing through the goods market. Since $I_t < M_t$, and these two variables are predetermined relative to X_t, a contractionary policy shock causes Γ_t to fall. That is, a monetary contraction creates a relative shortage of liquidity in financial markets. As explained in Fuerst (1992), Christiano (1991) and Christiano and Eichenbaum (1992, 1995) this leads to a reduction in employment and output. To see this, substitute out for the real wage using the labor supply equation, (3.16), make use of $N_t^{1-\alpha} = C_t$, $K_t = 1$,and rearrange, to obtain:

$$N_t = \left(\frac{1}{\psi_0}\Gamma_t\right)^{\frac{1}{\psi+\alpha}}. \tag{4.4}$$

Note that the size of the decrease in employment associated with a given reduction in X_t is monotonically increasing in the labor supply elasticity, $1/\psi$. With the labor supply elasticity large enough, and α small enough, the equilibrium response of employment to a money shock can be made arbitrarily large for given Γ_t. Since $P_t = (M_t + X_t)/N_t^{1-\alpha}$, this suggests there exists a value of ψ for which the equilibrium price level does not respond to X_t at all. This reasoning abstracts from general equilibrium effects of ψ on the level of Γ_t. But, we assume these are negligible, since the nonstochastic steady state level of Γ_t, Γ, and the value of $d\Gamma_t/dx_t$, evaluated in steady state, is invariant to ψ. To see this, note that $N_t^{-\alpha} = C_t/N_t$ when $K_t = 1$ and $\phi = 0$, so that:

$$\Gamma_t = \frac{W_t N_t}{P_t C_t} = \frac{1-\alpha}{\mu R_t}. \tag{4.5}$$

In steady state, $R = (1 + \mu_x)/\beta$, so that

$$\Gamma = \frac{1-\alpha}{\mu}\frac{\beta}{1+\mu_x}, \tag{4.6}$$

establishing that Γ is invariant to ψ. Next note that $d\Gamma_t/dx_t = (1 - i_t)/(1 + x_t)^2$,which in steady state equals $\left[1 - (\frac{1-\alpha}{\mu/\beta} - x)\right]/(1 + x)^2$. This establishes the invariance of the steady state value of $d\Gamma_t/dx_t$ to ψ.

To determine the effect of a contractionary monetary policy shock on the rate of interest, simply rearrange (4.5) to get:

$$R_t = \frac{1-\alpha}{\mu\Gamma_t}. \tag{4.7}$$

Since, $d\Gamma_t/dx_t > 0$ for $I_t < M_t$, (4.7) establishes that in this version of the model, a monetary contraction must drive the equilibrium rate of interest up.

Next we consider the impact of a monetary shock on profits. The time t economic profit of intermediate goods producers equals their total revenues minus total costs:

$$P_t Y_t - R_t W_t N_t - r_t K_t = P_t Y_t - MC_t(Y_t + \phi).$$

Recall from section 2 that the measure of profits used in our empirical analysis corresponds to accounting profits. While our empirical measure of profits nets out depreciation costs, a large portion of the return to capital (for example, dividends) is not treated as a cost. To adjust our model-based measure of economic profits to bring it closer in line with the empirical measure of profits, we add $r_t K_t$ to economic profits. This actually over-adjusts our measure of profits, because some components of rent to capital are treated as costs in our empirical measure of profits. However, one of our key conclusions is that the sticky price model counterfactually implies that profits rise after a monetary contraction. If anything, our treatment of the return to capital in profits biases our results in favor of the sticky price model. To summarize, the empirical measure of profits that we adopt is

$$\pi_t = P_t Y_t - MC_t(Y_t + \phi) + r_t, \tag{4.8}$$

where the equilibrium condition, $K_t = 1$ has been imposed.

To determine the impact of a monetary shock on π_t, note that (4.8) for the limited participation model reduces to:

$$\pi_t = (M_t + X_t)\left[1 - \frac{1}{\mu}\right] + \alpha N_t^{1-\alpha}, \tag{4.9}$$

where the first term uses (4.1) and (3.7) and the last term corresponds to the equilibrium rent on capital. Equations (4.4) and (4.9) indicate that profits necessarily fall in response to a fall in X_t. Note that adding r_t to economic profits exacerbates the decline in π_t after a decline in x_t.

It is of interest to understand the influence of the markup on the equilibrium effects of a monetary policy shock. From (4.4) it is clear that the effect on output of a monetary policy shock, dY_t/dx_t, can be decomposed into two components: (i) the effect of x_t on Γ_t, and (ii) the effect of Γ_t on N_t. Changes in μ affect dY_t/dx_t exclusively via the first channel. From (4.3) we see that in our model Γ_t corresponds to the share of labor in gross output. Not surprisingly, the larger is μ, the smaller is the steady state value of Γ (see (4.6)). Given μ_x, a smaller value of Γ corresponds to a smaller value of I/M, the fraction of households' beginning of period stock of money sent to the financial sector. The smaller is I/M, the larger is the impact of a given monetary injection on the pool of funds passing through the financial intermediary that are lent to firms. This implies that $d\Gamma_t/dx_t$ is larger which in turn leads to a rise in dN_t/dx_t and dY_t/dx_t (at least when evaluated in steady state). In this way, an increase in the markup raises the employment and output effects of a monetary policy shock. Note that the effect of an increase in μ on dN_t/dx_t and dY_t/dx is similar to the effect of an increase in $1/\psi$. However the mechanisms by which these effects occur are different. As we noted above, changes in the labor supply elasticity have a negligible impact on the magnitude of $d\Gamma_t/dx_t$ and a relatively large impact on dN_t/dx_t.

We conclude this section by noting that equation (4.9) implies that the increase in dN_t/dx_t associated with a larger value of μ also implies that a given monetary shock has a larger impact on profits. In addition, it is easy to verify that dR_t/dx_t is increasing (in absolute value) in μ, at least when evaluated in nonstochastic steady state. As is the case regarding dY_t/dx_t and dN_t/dx_t, the effects of an increase in μ are similar to those of an increase $1/\psi$, but the mechanisms by which these effects occur are different.

5. Quantitative Properties of the Sticky Price and Limited Participation Models

Before presenting the quantitative properties of the model, we discuss how values were assigned to the parameters.

5.1. Parameter Values

To compute the response of the system to monetary shocks, we require values for the models' parameters. This section describes the benchmark values used in our experiments. The models' structural parameters consist of β, α, ψ, μ, ϕ, ψ_0 and the parameters governing the evolution of x_t. We set the discount parameter β to $(1.03)^{-.25}$. The parameter ψ_0 is chosen so that, conditional on the assigned values for the other parameters, employment in nonstochastic steady state is unity.

The elasticity of labor supply with respect to the real wage rate is equal to $1/\psi$. The value of this elasticity has been a substantial source of controversy in the literature. Most microeconomic studies estimate it to be quite small. Typically, estimated labor supply elasticities for males are near 0 (see Killingsworth 1983, Pencavel 1986 or Card 1991). Estimates of labor supply elasticities for females typically fall in the range .5 − 1.5 (see for example Heckman and Killinsgworth 1986).

At the macroeconomic level, authors in the real business cycle literature typically work with labor supply elasticities that are much higher than those emerging from the labor literature. For example, the parameter estimates in Christiano and Eichenbaum (1992a) imply a Frisch labor supply elasticity in excess of 5. Authors like Hansen (1985) assume indivisibilities in labor supply and a market structure that breaks the connection between individual and aggregate labor supply elasticities. Given Hansen's functional form assumptions, the Frisch labor supply elasticity of the fictitious representative consumer whose preferences are used to compute the aggregate equilibrium is infinite. So the range of elasticities that have been used in the literature is enormous. We use a benchmark value for ψ equal to 1.0 corresponding to a labor supply elasticity of 1.0. We demonstrate that the models' empirical performance depends sensitively on this parameter by displaying results for a range of values for ψ.

Next, consider the parameters μ and ϕ. For intermediate good firms which set their price flexibly, μ corresponds to the markup in each period. For firms which set their price prior to the realization of the money shock, μ corresponds roughly to their average markup.[12] To discuss the relevant empirical range of values for μ and ϕ, it is useful to represent the production function of a typical intermediate good firm as $Y = F(K, N) - \phi$, where $F(K, N) = K^{\alpha}N^{1-\alpha}$. Profit maximization implies

$$F_K = \mu \frac{r}{P} \text{ and } F_N = \mu \frac{RW}{P}, \tag{5.1}$$

when firms set prices flexibly. This relation only holds approximately otherwise, though for the purposes of the following discussion, we assume the relation is exact. Let F_J denote the

[12] The correspondence is only approximate, since from (3.9), $EP_{it} = \mu E\omega_t MC_t = \mu Cov(\omega_t, MC_t) + \mu EMC_t \neq \mu EMC_t$, unless $Cov(\omega_t, MC_t) = 0$.

derivative of F with respect to $J \in (K, N)$. By our linear homogeneity assumption for F :

$$\frac{F_K K + F_N N}{Y} = \frac{F}{Y}. \tag{5.2}$$

Substituting (5.1) into the left side of (5.2) implies

$$\mu(1 - s_\pi) = \frac{F}{Y}, \tag{5.3}$$

where s_π is the share of economic profits, $PY - rK - RWN$, in total nominal output. Hall (1988), Basu and Fernald (1994) and Rotemberg and Woodford (1996), among others, argue that s_π is close to zero. Setting $s_\pi = 0$, we obtain

$$\mu = 1 + \frac{\phi}{Y} = \frac{1}{1 - \phi}, \tag{5.4}$$

since $Y = 1 - \phi$, given our procedure for choosing ψ_0. Our reading of the literature is that there is very little independent evidence on μ and $\frac{\phi}{Y}$.[13] For our benchmark parameterization, we follow Hornstein (1993) in adopting the value, $\mu = 1.20$. Given our diffuse priors on the size of $\frac{\phi}{Y}$, we also consider a range of other values of μ. We do this both with and without imposing (5.4).

We now consider the parameterization of the finite - state Markov chain for x_t. We suppose $x_t \in \{\mu_x - \sigma,\ \mu_x,\ \mu_x + \sigma\}$, and let $\pi^x = \{\pi^x_{ij}\}$, where $\pi^x_{ij} = prob\{x_{t+1} = x(j) | x_t = x(i)\}$, $i, j = 1, 2, 3$, and $x(j)$ corresponds to $\mu_x - \sigma$, μ_x, and $\mu_x + \sigma$, respectively, for $j = 1, 2, 3$. In our benchmark specification we set $\mu_x = 0.02$ and $\sigma = 0.017$. Also, we specify that x_t is iid by setting each entry in π^x to 1/3. We also consider an alternative parameterization in which money growth is positively autocorrelated. For this, we assume the elements of π^x are symmetric, so that there are five free parameters in the stochastic process for $\{x_t\}$: three in π^x and the two in $x(j)$, $j = 1, 2, 3$. We pin these down by requiring that (1) the autocorrelation of x_t be 0.5, (2) the standard deviation of the error in regressing x_t on one lag of itself be 0.01, (3) $\{x_t\}$ have the kurtosis of a normal distribution, namely, 3, (4) the

[13]See Rotemberg and Woodford (1996) for a brief review of the literature.

mean growth rate of x_t is 0.02. Finally, we arbitrarily set the 1,2 element of π to 1/3.[14]

Our specification of the Markov chain for x_t implies that the growth rate of money has a first order autoregressive representation, with an AR coefficient equal to either 0.0 or 0.5. At first glance, this parameterization might appear to be inconsistent with the empirical analysis of section 2. There we considered monetary policy rules that are highly reactive to the state of the economy. Indeed, the view taken in both CEE and SZ is that the aim of monetary policy is to bring about a particular relationship between various endogenous variables. These relationships are given by (2.1) and (2.2), respectively. However for either of these relationships to hold in equilibrium, the growth rate of money must respond to current and past exogenous shocks (e.g., innovations in preferences, technology, sunspots, monetary policy shocks) in an appropriate way. Under the identifying assumptions of CEE and SZ, an estimate of the way x_t responds to current and past monetary policy shocks is given by the estimated dynamic response function of x_t to a policy shock. Christiano, Eichenbaum and Evans (1996a) argue that when 'money' is measured by $M2$, a reasonable time series representation for the response of x_t to a policy shock is a first order autoregressive representation ($AR(1)$) with AR coefficient equal to 0.5. We refer the reader to Christiano, Eichenbaum and Evans (1996a) for details.[15]

There are two points worth emphasizing about our parameterization of monetary policy. First, we emphasize that we do not adopt the $AR(1)$ specification based on an appeal to the

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[14]For further details about this procedure for parameterizing a three-state Markov chain, see Christiano (1990). We used: $\pi^x = \begin{pmatrix} 0.58 & 0.33 & 0.08 \\ 0.08 & 0.83 & 0.08 \\ 0.08 & 0.33 & 0.58 \end{pmatrix}$, and $x_t \in \{0.0, 0.02, 0.04\}$.

[15]The argument in Christiano, Eichenbaum and Evans (1996a) can be summarized very simply, with the aid of a money demand equation in a diagram with the nominal interest rate on the vertical axis and the money stock on the horizontal axis. Suppose, in the spirit of section 2 above, that policy is represented as an interest rate target, with $\psi \equiv 0$ in (2.1) and two possible values for $\varepsilon_s : \varepsilon_s^h, \varepsilon_s^l$. Then, policy can be represented by two horizontal lines, with intercepts $R^h = \varepsilon_s^h$ and $R^l = \varepsilon_s^l$. Denote the equilibrium money stocks associated with these two interest rates by M^h and M^l. Then, we have two equivalent ways to represent policy. One is the one already cited, namely two horizontal lines with intercepts, $\{R^h, R^l\}$. The other represents monetary policy by a money supply rule with vertical lines at M^h and M^l. Corresponding to these two equivalent ways of representing policy there are two methodologies for testing the model, here summarized by the downward-sloped money demand schedule. One way is to specify policy as $\{R^h, R^l\}$ and verify that the $\{M^h, M^l\}$ predicted by the theoretical money demand curve holds in the data. This is equivalent to incorporating the interest rate rule into the model and verifying that the impulse response from monetary policy shocks to money in the model matches the one estimated from the data. Alternatively, one could specify policy as $\{M^h, M^l\}$ and verify that $\{R^h, R^l\}$ holds in the data. The methodology we adopt in this paper is in the spirit of the latter.

univariate properties of the raw $M2$ growth data. To do so would be hard to square with our empirical analysis, according to which monetary policy is reactive to the state of the economy. Second, there is an important caveat to our analysis: the $AR(1)$ representation used here is not a very good approximation to the response of the growth rate of the base or $M1$ to a policy shock in either the CEE or SZ systems. These are better approximated by a short moving average representation in which the response of x_t to a policy shock is initially small and then becomes larger. An important question for further research is the extent to which the results discussed below are robust to alternative specifications for the growth rate of money.

Finally, we turn to the parameter, α. Estimates in Christiano (1988, footnote 3), based on the National Income and Product Accounts, suggest that the share of income going to labor, W_tN_t/Y_t, averages roughly 0.64. In the version of our model with $\phi \neq 0$, (4.5) becomes:

$$\Gamma_t = \frac{1-\alpha}{\mu R_t}\frac{N_t^{1-\alpha}}{N_t^{1-\alpha}-\phi},$$

or, after using (5.4) and imposing that in steady-state, $N_t = 1$,

$$\alpha = 1 - R\Gamma. \tag{5.5}$$

Given the parameter values already specified, $R = (1+\mu_x)/\beta = 1.0276$. With this and $\Gamma = 0.64$, (5.5) implies $\alpha = 0.34$. In our calculations, we used $\alpha = 0.36$.

5.2. Results

Our results are reported in Tables 1 and 2, which displays the contemporaneous equilibrium response of the system to an unanticipated fall in the growth rate of the money stock from μ_x to $\mu_x - \sigma$. In that table, dp denotes the percent change in the price level associated with a one percent unanticipated change in the end of period stock of money. Specifically,

$$dp = log(p'/p)/log((1+\mu_x)/(1+\mu_x-\sigma)),$$

where p denotes the price level in state $x_t = \mu_x$ and p' denotes the price level in state $x_t = \mu_x - \sigma$. The variables, dc, dn, dw, $d\pi$ and dMC refer to the analogous responses of consumption, employment, the real wage, profits and marginal costs, respectively. The variables dR represents the simple change in the nominal rate of interest, scaled by $log((1+\mu_x)/(1+\mu_x-\sigma))$. The variable χ in Table 1 denotes the level of the markup when money growth is $\mu_x - \sigma$ in the current period, and was μ_x in the previous period.

5.2.1. The Sticky Price Version of the Model

The two most salient failings of the benchmark sticky price model are its counterfactual implications that profits *rise* and the interest rate *falls* in response to a monetary contraction. For example, Panel A of Table 1 indicates that, for the benchmark parameter values, an unanticipated 1% contraction in the money stock generates a 2.95% rise in economic profits and a 79 basis point fall in the interest rate. We consider each of these failings in turn and show that the model's counterfactual implication for the interest rate can be overturned but that its counterfactual implication for profits is more fundamental.

To understand the benchmark sticky price model's implications for the response of profits to a contractionary monetary policy shock, recall that in equilibrium, time t profits can be written as

$$\pi_t = (M_t + X_t)\left[\frac{P_t - MC_t}{P_t}\right] - MC_t\phi + r_t. \tag{5.6}$$

Here we made use of the fact, $P_tC_t = M_t + X_t$. In what follows it is useful to recall (3.6), $MC_t = \frac{1}{1-\alpha}N_t^{\alpha}W_tR_t$.

As we discussed, final good prices inherit the inflexibility of intermediate goods prices, so that $dp = 0$. Consequently, consumption and output fall by the same percentage as the money stock. With output in the intermediate good industry lower, aggregate employment is also lower. In the sticky price model, this corresponds to a movement along the aggregate supply curve of labor. Given our assumed labor supply elasticity, this generates a large fall in the real wage rate equal in magnitude to the percentage decline in employment (1.30%). With the interest rate, the wage rate and employment falling, marginal costs decline and the markup rises by six percentage points, from 1.20 to 1.26. In equilibrium the rental rate r_t is given by $r_t = \frac{\alpha}{1-\alpha} N_t W_t R_t$, so it too falls. The rise in the markup overwhelms the fall in r_t and output. The result is that profits *rise* after a monetary contraction.

The previous discussion suggests a variety of perturbations to assess the robustness of this result. The perturbations which we consider were motivated by a desire to identify versions of the model in which marginal costs fall by less after a monetary contraction. The first set of changes we consider are variations in the elasticity of labor supply. Panel B of Table 1 reveals that increasing the elasticity of labor supply does reduce the fall in wages and mitigates the rise in profits. However even if we increase the elasticity to the incredible value of 10, we still do not overturn the basic result that profits rise after a contractionary monetary shock. Panels C and D and row 2 of Panel E, in Table 1, document that the profit result is robust to variations in μ and ϕ. Panel C varies μ while changing ϕ according to (5.4) and holding all other parameter values at their benchmark values. Panel D varies μ, holding all other parameters (including ϕ) fixed at their benchmark values. Row 2 of Panel E sets $\phi = 0$, holding all other parameter values to their benchmark values.

The next perturbation we consider is to increase the power on labor in the production function. With a reduction in curvature on labor in the production function, a 1% fall in consumption requires a smaller decline in N_t. For a given elasticity of labor supply, this means that real wages fall less in response to the contractionary money shock. Other things the same, this reduces the downwards pressure on the markup and marginal costs, and the upwards pressure on profits. There is however a key countervailing force. As α goes to zero, the capital costs drop from profits. The first row of Panel E of Table 1 reveals that this latter effect dominates by a large margin. Now, with $\alpha = 0$, profits almost triple after a contractionary monetary policy shock.

Next we consider the effect of reducing the percentage of firms that set prices in advance. First, we consider the case in which 80% of the firms set prices according to (3.9), and 20% set prices flexibly, according to (3.7). With a subset of firms setting prices flexibly, output and employment ought to fall by less in response to an unanticipated monetary contraction. This should reduce the downward pressure on marginal costs and thereby lessen the upward pressure on profits. The first row of Panel F reports results for this case and verify the previous conjectures: the rise in profits is now less than the rise reported for the benchmark model. However, the impact on the magnitude of the rise in profits is small. Further reductions in the number of price setters are likely to produce additional improvements in the model's predictions for the response of profits. However, these improvements come at a severe cost: a given reduction in the fraction of price setters produces a disproportionately large fall in the price level, and a disproportionate dampening in the response of output to a contractionary monetary policy shock. This reflects the absence of 'strategic complementarity' in price setting in our model. With a one percent money contraction, a given flexible price setter drops its price by *more*, the *larger* is the fraction of firms fixing prices. This happens because the larger is the fraction of firms fixing prices, the greater is their reduction in output with a given money contraction and therefore the greater is the general equilibrium reduction in marginal costs as they employ fewer factors of production. This accounts for the greater reduction in price by the flexible firms, who simply set price as a given markup over marginal costs. A further discussion of what happens in our model economy when there is a mixture of flexible and fixed price firms, is contained below. The second row of Panel F reports results for the case in which 20% of the firms set price in advance. Consistent with the discussion above, this economy looks very much like a standard cash in advance economy. Profits do fall after a contraction but now $dp = -.91$ and $dc = -.09$.

All versions of the sticky price model that we have considered so far imply that the interest rate falls with a monetary contraction. It is of interest for two reasons to consider perturbations of the model in which the interest rate *rises* after a monetary contraction. The first is that this is consistent with the data. The second is that the interest rate decline is partially responsible for the fall in marginal costs and the rise in profits that occurs in the benchmark model after a contractionary monetary policy shock.

With the following utility function, we can reverse the implications of the benchmark model for the interest rate:

$$U(C,N) = \frac{C^{1-\gamma}}{1-\gamma} - \psi_0 \frac{N^{(1+\psi)}}{1+\psi}. \tag{5.7}$$

To see this, note that the household's Euler equation, (3.17), and $P_tC_t = M_t + X_t$ imply:

$$C_tU_{c,t} = \beta R_t A, \text{ where } A = E_t \frac{C_{t+1}U_{c,t+1}}{M_{t+2}/M_{t+1}}. \tag{5.8}$$

The fact that A is constant reflects the benchmark model's *iid* assumption on the growth rate of money. Relations (5.7) and (5.8) imply:

$$R_t = \frac{C_t^{1-\gamma}}{\beta A} = \frac{[M_t + X_t]^{1-\gamma}}{\beta A P_t^{1-\gamma}}.$$

Since P_t and M_t are predetermined relative to X_t, it follows that an increase in X_t drives R_t down for $\gamma > 1$, and has no impact on R_t for $\gamma = 1$.

Rows 3-5 of Panel E in Table 1 report the results of adopting specification (5.7) of the utility function for the basic sticky price model. Row 3 reports results for the case, $\gamma = \psi = 1$. As expected, the interest rate is unaffected by a contractionary monetary policy shock. The basic result, that profits rise after a monetary contraction is unaffected. Indeed, the rise in profits is even larger than in the benchmark model.

The basic intuition for this result is as follows. With the new utility function, the household's Euler equation for labor is given by:

$$\frac{W_t}{P_t} = \psi_0 C_t^{\gamma} N_t^{\psi}.$$

This resembles the labor supply equation in the benchmark model, (3.16), with one important difference: now, a decrease in consumption shifts the labor supply curve to the right. It is still the case that a one percent decrease in the money supply produces a one percent drop in consumption. Since the production technologies in the two specifications are identical, the drop in employment must be the same. But, with the new labor supply curve, the drop in consumption leads to a larger fall in the real wage rate and marginal cost. This is why the markup and profits rise by even more than in the benchmark specification (see row 1 of Panel A, Table 1).

Row 4 of Panel E presents results for the same specification as row 3, except that $\gamma = 2$. Now the interest rate actually rises in response to the monetary contraction. However, this effect is offset by a greater fall in the wage rate, with the consequence that profits continue to rise. Row 5 allows for a money growth rate process whose Wold representation is a first order autoregression with a lag coefficient equal to 0.5, and innovation standard deviation of 0.01. Despite the anticipated inflation effects that now come into play, the interest rate continues to rise. The counterfactual implications for profits are not affected.

To summarize our results, we find that the sticky price model fails on two key dimensions of the data. First, it implies that profits rise after an unanticipated monetary contraction. Second, and closely related, for plausible labor supply elasticities, it implies large declines in the wage rate following a contractionary monetary policy shock. An additional source of concern about the sticky price model is that the benchmark version implies interest rates fall after a contractionary monetary policy shock. We did identify a perturbation to the model that remedies this shortcoming. However, it exacerbates the other two empirical shortcomings of the model.

5.2.2. The Limited Participation Model

In this section we consider the ability of the limited participation version of the model to account, at least in a stylized way, for the empirical regularities documented above. We show that this version of the model does at least as well, if not better than the sticky price model. Specifically, it has no difficulty generating a rise in the interest rate and a fall in profits after a contractionary monetary policy shock. Moreover, it is capable of producing small price and large output responses, but its ability to do so depends on the assumed labor supply elasticities and markups.

Our quantitative results for the benchmark specification are reported in the first row of Panel A of Table 2. The key features are as follows. First, in contrast to the benchmark sticky price model, the interest rate rises, and profits fall, in response to a one percent permanent reduction in the money stock. The key failing of the benchmark model is that the primary impact of the policy shock is on prices and not on output. Specifically, prices fall by 0.62 percent and output falls by 0.38 percent.

We now consider a series of perturbations motivated by the desire to increase the output response and decrease the price response of the system to a monetary policy shock. Panel B reports the results of varying the elasticity of labor supply. As expected based on the reasoning leading to equation (4.4), perturbations which increase the value of $1/\psi$ work in the right direction. Indeed, at a labor supply elasticity of 5, the output response is so large (-1.1 percent) that prices actually *rise* in response to an unanticipated contractionary monetary policy shock. For all labor supply elasticities reported, the interest rate rises and profits fall in response to the shock.

Panel C of Table 2 reports the results of varying the markup. As in Panel C of Table 1, we simultaneously change ϕ so that there are no economic profits in steady state. Two key features of the results are worth noting. First, increases in the markup move the model in the desired direction. Specifically, the sensitivity of the price level to the policy shock declines, while the sensitivity of output rises. Second, if we set the markup to 1.4, the value assumed by Rotemberg and Woodford (1996), we can lower the labor supply elasticity to 2, and obtain the result that the price level hardly moves in response to a contractionary monetary policy shock ($dp = -.08$ percent, and $dc = -0.92$ percent). While this labor supply elasticity is high relative to some micro-based estimates, it is small relative to the range considered in the real business cycle literature.

Panel D reports the results of varying the markup, holding ϕ constant at its benchmark value. Consistent with the discussion in section 4.2, an increase in μ (i) increases the extent of the fall in employment, consumption and the real wage, (ii) increases the rise in the interest rate, and (iii) mutes the response of the fall in the price level. Comparing Panels C and D we see that decreases in ϕ per se, have the same qualitative effect on the response of the system to a contractionary policy shock as an increase in μ. A different way to see this is to compare the results for the benchmark parameter values (row 1, Panel A) with the results in row 2, Panel E which are obtained with the benchmark parameter values except that ϕ is set to zero.

For completeness, panel E of Table 2 reports the results of the experiments analogous to those analyzed in panel E of Table 1. The two main findings are as follows. First, increasing the share of labor leads to a deterioration of the benchmark model's performance.

Specifically, prices respond by more to a contractionary monetary policy shock. Moreover, profits actually rise. Second, the effect of moving to the alternative functional form for utility has relatively little impact on the model's performance. Relative to the benchmark model, the output effect is somewhat weaker and the price effect, somewhat stronger. This is consistent with the intuition offered above, according to which the change in functional form has effects similar to a reduction in the labor supply elasticity.

One obvious perturbation of the limited participation model is to assume that a subset of the intermediate good firms set their price in advance of the realization of x_t, thus magnifying the effect of a policy shock on aggregate output. Panel F considers the consequences of assuming that 80 percent of the intermediate goods firms set prices in advance. The first row reports the impact of the change on our benchmark specification. Interestingly, the impact is quite small. With the change, the price and output responses are -0.48 and -0.52 percent, respectively. These are to be compared with the -0.62 and -0.38 figures from Panel A. The reason that adding price setters does little to reduce the price effect of a money shock is very similar to the reasoning we used to explain the consequences of reducing the percentage of price setters in the sticky price model from 100% to 80%. (See Panel F of Table 1). For the 80 percent of firms who set prices in advance in the limited participation model, the output effect of a money contraction is greater than in the equilibrium when everyone sets prices flexibly. In particular, their output falls by a full 3.39 percent, and their employment falls by 3.00 percent. The key to understanding the relatively small effect of a money contraction on aggregate output and the relatively large effect on the price level is to consider the price and output response of the other 20 percent of intermediate goods producers, who set prices flexibly. The large drop in employment by the fixed price firms leads to a large drop in the marginal cost of production. According to Panel A, the marginal cost of production falls by 0.62 percent when *all* prices are set flexibly. In contrast, marginal costs fall by 2.06 percent when 80 percent of firms fix prices in advance. This drop in marginal costs leads the flexible price firms to drop their prices by 2.06 percent and to actually *increase* output and employment, by 8.96 percent and 7.46 percent, respectively. In effect, it is the complete absence of 'strategic complementarity' in price setting that accounts for the small impact of price setting in the model: flexible price setters are encouraged to reduce prices by more, the larger is the fraction of firms which fix prices in advance. For completeness, row 2 of Panel F reports results for the case in which 20% of the firms set price in advance. Consistent with the discussion above, the results are extremely similar to that which we obtain when *none* of the firms set price in advance (se row 1 of Panel A, Table 2).

The previous reasoning suggests that introducing sticky price firms into the limited participation model would have a greater impact on reducing the price effect of a money shock if we incorporated limitations on the intersectoral mobility of factors of production. To investigate this possibility we modified the version of the limited participation model in which the fraction $(1-v)$ of the intermediate good firms set prices in advance as follows. Denote the sector of the economy in which intermediate good firms set prices flexibly and the sector in which they set prices in advance as sector 1 and 2, respectively. Assume that fraction v and $(1-v)$ of the population works in sectors 1 and 2, respectively. The assumption that v is not a state dependant choice of the household captures limited intersectoral immobility of labor. We modify the preferences of the representative household as follows:

$$U(C, N_1, N_2) = log\left\{C - v\frac{\psi_0}{1+\psi}N_1^{1+\psi} - (1-v)\frac{\psi_0}{1+\psi}N_2^{1+\psi}\right\}, \tag{5.9}$$

where N_i denotes hours of work in sectors $i = 1, 2$, respectively. The time t wage rate in sector i is given by W_{it}, $i = 1, 2$. The cash constraint on the household's consumption purchases, (3.14), is replaced by the constraint

$$P_tC_t \leq vW_{1t}N_{1t} + (1-v)W_{2t}N_{2t} + M_t - I_t. \tag{5.10}$$

The household is endowed with one unit of capital which it allocates to capital markets in the two sectors of the economy subject to the constraint

$$vK_{1t} + (1-v)K_{2t} = 1. \tag{5.11}$$

Here K_{it} denotes the amount of capital supplied to sector $i = 1, 2$. The time t rental rate on capital in sector i given by $r_{it}, i = 1, 2$. The household chooses K_{it} before the time t realization of X_t. This assumption captures limited intersectoral mobility of capital.

We replace (3.15), which governs the evolution of the household's money holdings, with

$$
\begin{aligned}
M_{t+1} &= [vW_{1t}N_{1t} + (1-v)W_{2t}N_{2t} + M_t - I_t - P_tC_t] \\
&\quad + r_{1t}vK_{1t} + (1-v)r_{2t}K_{2t} + R_t[I_t + X_t] + D_{1t} + D_{2t}.
\end{aligned} \tag{5.12}
$$

Here D_{1t} and D_{2t} denote time t profits from intermediate good producers in the two sectors.

The household maximizes (5.9) subject to (5.10) - (5.12). It chooses C_t, N_{1t}, N_{2t} and M_{t+1} after the realization of X_t. It chooses I_t, K_{1t} and K_{2t} before the realization of X_t.

The first order necessary conditions associated with the household's choice of N_{it} are given by

$$\frac{W_{it}}{P_t} = \psi_0 N_{it}^{\psi} \tag{5.13}$$

for $i = 1, 2$. The Euler equation for I_t is still given by (3.18). The household's Euler equations for K_{1t} and K_{2t} imply that

$$E_{t-1}\frac{U_{c,t+1}}{P_{t+1}}(r_{1t} - r_{2t}) = 0. \tag{5.14}$$

The problem of the final goods firm is unaffected, so that the demand equation for intermediate good i is still given by (3.2). The problems of the intermediate good firms in the two sectors are the same as described in section 3 of the paper. As before we confine ourselves to symmetric equilibria. Let K_{it} and N_{it} denote the amount of capital and labor hired by the typical firm in sector $i = 1, 2$. Firms' Euler equations for K_{it} and N_{it} imply

$$\frac{r_{it}}{W_{it}R_t} = \frac{\alpha}{1-\alpha}\frac{N_{it}}{K_{it}}, \tag{5.15}$$

$i = 1, 2$. The typical firm in the flexible price sector continues to set its price as a constant markup over marginal cost, according to (3.7). The typical firm in the inflexible price sector continues to set its price as a constant markup over a weighted expectation of marginal cost, according to (3.9) and (3.10). Marginal cost for the two types of firms is given by

$$MC_{it} = A\left(\frac{r_{it}}{W_{it}R_t}\right)^{\alpha} W_{it}R_t \tag{5.16}$$

$i = 1, 2$, where A is defined immediately after (3.5). Economy wide output is given by

$$Y_t = \left[v\left(\left(\frac{K_{1t}}{N_{1t}}\right)^{\alpha} N_{1t} - \phi\right)^{\frac{1}{\mu}} + (1-v)\left(\left(\frac{K_{2t}}{N_{2t}}\right)^{\alpha} N_{2t} - \phi\right)^{\frac{1}{\mu}} \right]^{\mu}, \tag{5.17}$$

and the economy wide price level is given by

$$P_t = \left[vP_{1t}^{\frac{1}{1-\mu}} + (1-v)P_{2t}^{\frac{1}{1-\mu}} \right]^{1-\mu}. \tag{5.18}$$

The loan market clearing condition (3.11) is replaced by

$$vW_{1t}N_{1t} + (1-v)W_{2t}N_{2t} = I_t + X_t. \tag{5.19}$$

Finally, the definition of an equilibrium is the same as that given in section 3, except that W_t and r_t are replaced by (W_{1t}, W_{2t}) and (r_{1t}, r_{2t}), respectively. We compute an equilibrium by solving a suitably modified version of the nonlinear equations discussed there.

Panel G of Table 2 reports the response of the previous model economy to a monetary policy shock assuming our benchmark parameter values and that 20% of the firms set prices in advance (i.e., $v = .8$). Comparing these results to row 2 of Panel F, Table 2, we see that introducing limited intersectoral mobility does reduce the magnitude of *dp* and does increase the magnitude of *dc* and *dn*. However, these effects are small and come at a large cost - now, the interest rate falls and profits rise after a contractionary shock.[16]

The introduction of limitations on intersectoral mobility of factors of production evidently helps very little. To gain intuition into this result, recall that fixed price firms substantially

[16]For the purpose of these calculations, $N_t = vN_{1t} + (1-v)N_{2t}$ and $W_t = (vW_{1t}N_{1t} + (1-v)W_{2t}N_{2t})/N_t$. Also, $dMC_{1t} = -5.73$ and $dMC_{2t} = -7.56$.

reduce their use of productive resources when there is a monetary contraction. Absent limitations on intersectoral mobility, this results in a large flow of resources from the fixed price sector to the flexible price sector. The resulting downward pressure on factor costs encourages flexible price firms to cut prices and expand output. Limitations on the intersectoral mobility of factors limits this phenomenon - labor and capital released from the fixed price sector cannot find their way to the flexible price sector in the period of a monetary shock. As a result, the contraction of the fixed price sector does not release capital and labor for use in the flexible price sector. However, limited the intersectoral mobility assumption does not limit the intersectoral flow of cash. The contraction of the fixed price sector results in a drop in the demand for money by firms in that sector. This appears to have reduced the equilibrium interest rate, driving down marginal costs of flexible price firms fall and encouraging them to cut prices and increase output.

We now summarize our results for the limited participation model. Our major finding is as follows. If one is willing to assume a reasonably high markup (e.g., 40 percent) and a high labor supply elasticity (e.g., 2 percent), then the limit participation model can account in a stylized way for the facts stressed in this section. Specifically, an iid shock to the growth rate of money has essentially no contemporaneous impact on the price level, and drives wages, profits, output and employment down, while driving the rate of interest up. If one is not willing to accept high markups and labor supply elasticities, then the model has difficulty in generating a large output effect and a small price effect from a monetary policy shock. From this perspective, a fruitful avenue for future research would be to investigate labor market frictions which raise the effective elasticity of labor supply. An obvious candidate is wage contracting.

6. Conclusion

This paper assessed the ability of two classes of models to account for the salient facts about how the economy responds to an unanticipated monetary policy shock. Each class of models stressed a particular type of friction that generated monetary nonneutrality. The first friction was sticky good prices. The second friction was households' sluggish demand for money. Both models suffered from important, related shortcomings. In our view, a model that convincingly accounts for the key effects of a monetary policy shock will have to allow for labor market frictions, whose effect is to increase the effective elasticity of labor supply, in addition to the frictions considered in this paper.

The key problem with the sticky price model is that it could not account for the fact that profits fall after a contractionary policy shock. Indeed, the model has the perverse implication that profits actually rise after such a shock. This happens because, absent labor market frictions or an implausibly high labor supply elasticity, marginal costs fall and markups rise sharply after a contractionary monetary policy shock. One obvious friction which would help overturn the model's counterfactual implications is the presence of wage contracts. If these had the property that employment falls after a contractionary policy shock but wages do not, marginal costs would not drop by so much after a contractionary monetary policy shock and profits would not rise. Allowing for endogenous capacity utilization could also render the sticky price model consistent with the key facts. As Burnside and Eichenbaum (1996) stress, with endogenous capacity utilization, the supply of capital services to the economy is no longer predetermined in any given period. Consequently, employment and marginal costs would not fall so much in response to a contractionary policy shock. This could well overturn the sticky price model's counterfactual implications for profits.

The key problem with the limited participation model was that it could not account for the fact that prices do not immediately respond to a monetary shock, at least not with a plausible labor supply elasticity. Allowing for wage contracts which effectively increased the response of employment to monetary shocks, would clearly improve the model's performance. So too would endogenous capacity utilization which magnified the response of output to shocks. An important additional advantage of allowing for endogenous capacity utilization is that it could render both the sticky price and limited participation models consistent with the fact that labor productivity is procyclical.

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8. Appendix A

The following time series were used in estimating the CEE policy shock measures.

Logged GDP in fixed-weight 1987 dollars, seasonally adjusted; logged GDP deflator derived from nominal GDP and GDP in fixed weight 1987 dollars, SA; change in index of sensitive materials prices, including commodity prices, smoothed; federal funds rate; logged nonborrowed reserves, SA; logged total reserves, SA; and the change in the log of M2, SA. All these data series were taken from the Federal Reserve Board's macroeconomic database.

The following time series were used in estimating the SZ policy shock measures.

Logged producer price index crude materials, SA; logged producer price index intermediate materials, SA; logged GDP in fixed-weight 1987 dollars, SA; logged GDP deflator derived from nominal GDP and GDP in fixed weight 1987 dollars, SA; 3-month Treasury bill rate; and change in the log of M2, SA. All these data series were taken from the Federal Reserve Board's macroeconomic database. Logged average hourly earnings of private nonagricultural production workers, divided by the GDP deflator, SA, from Citibase data set.

The following measures of real wages were used in our estimation exercises.

Average hourly earnings (AHE) of private nonagricultural production workers (1964:Q1 to 1995:2); AHE of private nonagricultural production workers, deflated by the Bureau of Labor Statistics using a derivation of the Consumer Price Index for Urban Wage Earners and Clerical Workers (1964:Q1 to 1992:3); AHE of manufacturing sector; AHE of manufacturing durable goods sector; AHE of manufacturing nondurable goods sector; AHE of food and kindred product sector; AHE of tobacco manufacturing sector; AHE of textile mill products sector; AHE of apparel and other textile products sector; AHE of paper and allied products sector; AHE of printing and publishing sector; AHE of chemicals and allied products sector; AHE of petroleum and coal products sector; AHE of rubber and miscellaneous plastics products sector; AHE of leather and leather products sector; AHE of lumber and wood products sector; AHE of furniture and fixtures sector; AHE of stone, clay and glass products sector; AHE of primary metal industries sector; AHE of fabricated metal products sector; AHE of machinery – except electrical – sector; AHE of electric and electronic equipment sector; AHE of transportation equipment sector; AHE of instruments and related products sector; and AHE of miscellaneous of durable manufacturing goods sector. All wages are from the Citibase data set and are seasonally adjusted. All wage data are divided by the GDP deflator and are logged, except where noted.

The profit data used in our analysis are accounting profits, namely income earned in current production. See BEA (1985). The following measures of corporate profits were used in our empirical exercises.

Profits before tax with inventory valuation and capital consumption adjustment, SA; Profits after tax with inventory valuation and capital consumption adjustment, SA; Net domestic profits after tax with inventory valuation and capital consumption adjustment, SA; Nonfinancial net domestic profits after tax with inventory valuation and capital consumption adjustment, SA; Profits after tax excluding net interest costs, SA; Net domestic profits after tax excluding net interest costs, SA; Nonfinancial net domestic profits after tax excluding net interest costs, SA; Domestic manufacturing profits before tax with inventory valuation adjustment, SA; Domestic durable goods manufacturing profits before tax with inventory valuation adjustment, SA; Domestic nondurable goods manufacturing profits before tax with inventory valuation adjustment, SA; Domestic transportation and public utilities profits before tax with inventory valuation adjustment, SA; Domestic retail trade profits before tax with inventory valuation adjustment, SA; All profit series were taken from the Federal Reserve Board's macroeconomic database.

As explained in BEA (1985) for corporate profits with inventory valuation adjustment and capital consumption adjustment, profits are measured as receipts less expenses as defined in Federal tax law. However, receipts exclude capital gains and dividends received, expenses exclude depletion and capital losses, inventory withdrawals are valued at current replacement cost, and depreciation is on a consistent accounting basis and valued at current replacement cost.

9. Appendix B

In this appendix we describe the identification scheme underlying our version of the SZ policy shock measure. Suppose that the economy is described by a structural model of the form

$$B_0 Z_t = B_1 Z_{t-1} + ... + B_q Z_{t-q} + \varepsilon_t. \tag{9.1}$$

Here Z_t denotes an l dimensional vector of observable variables, B_i is a l by l dimensional matrix, $i \in [1, ..., q]$, the diagonal elements of B_0 are unity, B_0 is assumed to be invertible, and ε_t is a l dimensional vector of structural disturbances to the economy. The vector ε_t is assumed to be uncorrelated with Z_{t-j}, for all $j > 0$, and the covariance matrix of ε_t,

$$E\varepsilon_t \varepsilon_t' = \Lambda \tag{9.2}$$

is diagonal. The diagonal elements of Λ are the variances of the structural shocks to the economy. Relation (9.1) implies the following reduced form VAR for Z_t :

$$Z_t = A_1 Z_{t-1} + ... + A_q Z_{t-q} + u_t. \tag{9.3}$$

The covariance matrix, Σ, of u_t, is

$$\Sigma = (B_0^{-1})\Lambda(B_0^{-1})'. \tag{9.4}$$

The A_i's are given by

$$A_i = B_0^{-1} B_i. \tag{9.5}$$

The disturbance term u_t is related to ε_t via the relationship,

$$u_t = B_0^{-1} \varepsilon_t. \tag{9.6}$$

The vector Z_t includes the log of crude materials prices (Pcm), the first difference of the log of M2 ($M2$), the three-month Treasury bill rate ($Tbill$), the log of intermediate materials prices (Pim), the log of the implicit GDP deflator (P), the log of real wages (W/P), and the log of real GDP (Y). Sims and Zha (1995) achieve identification by the following specification of the B_0 matrix.

$$\begin{bmatrix} \varepsilon_{Pcm} \\ \varepsilon_{MD} \\ \varepsilon_{MP} \\ \varepsilon_{Pim} \\ \varepsilon_{P} \\ \varepsilon_{w/p} \\ \varepsilon_{y} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & B_{13} & B_{14} & B_{15} & B_{16} & B_{17} \\ 0 & B_{22} & B_{23} & 0 & B_{25} & 0 & B_{27} \\ B_{31} & B_{32} & B_{33} & 0 & 0 & 0 & 0 \\ B_{41} & 0 & 0 & B_{44} & B_{45} & B_{46} & B_{47} \\ B_{51} & 0 & 0 & 0 & B_{55} & B_{56} & B_{57} \\ B_{61} & 0 & 0 & 0 & 0 & B_{66} & B_{67} \\ B_{71} & 0 & 0 & 0 & 0 & 0 & B_{77} \end{bmatrix} \begin{bmatrix} u_{Pcm} \\ u_{M2} \\ u_{Tbill} \\ u_{Pim} \\ u_{P} \\ u_{w/p} \\ u_{y} \end{bmatrix} \tag{9.7}$$

along with the overidentifying restriction that $B_{25} = B_{27} = -B_{22}$. We refer the reader to Sims and Zha (1995) for a discussion of this identification scheme. In our version of SZ, we do not impose restrictions on B_{25} and B_{27}.

For our analysis of profits, we augmented the vector Z_t to include the ratio of profits to GDP ($Prof$). Identification in the 8-variable system is achieved by adding an eighth row and column to B_0 in (9.7) for ε_{Prof} and u_{Prof}. The additional non-zero elements in B_0 are $B_{18}, B_{48}, B_{58}, B_{68}, B_{78}, B_{81},$ and B_{88}.

Figure 1

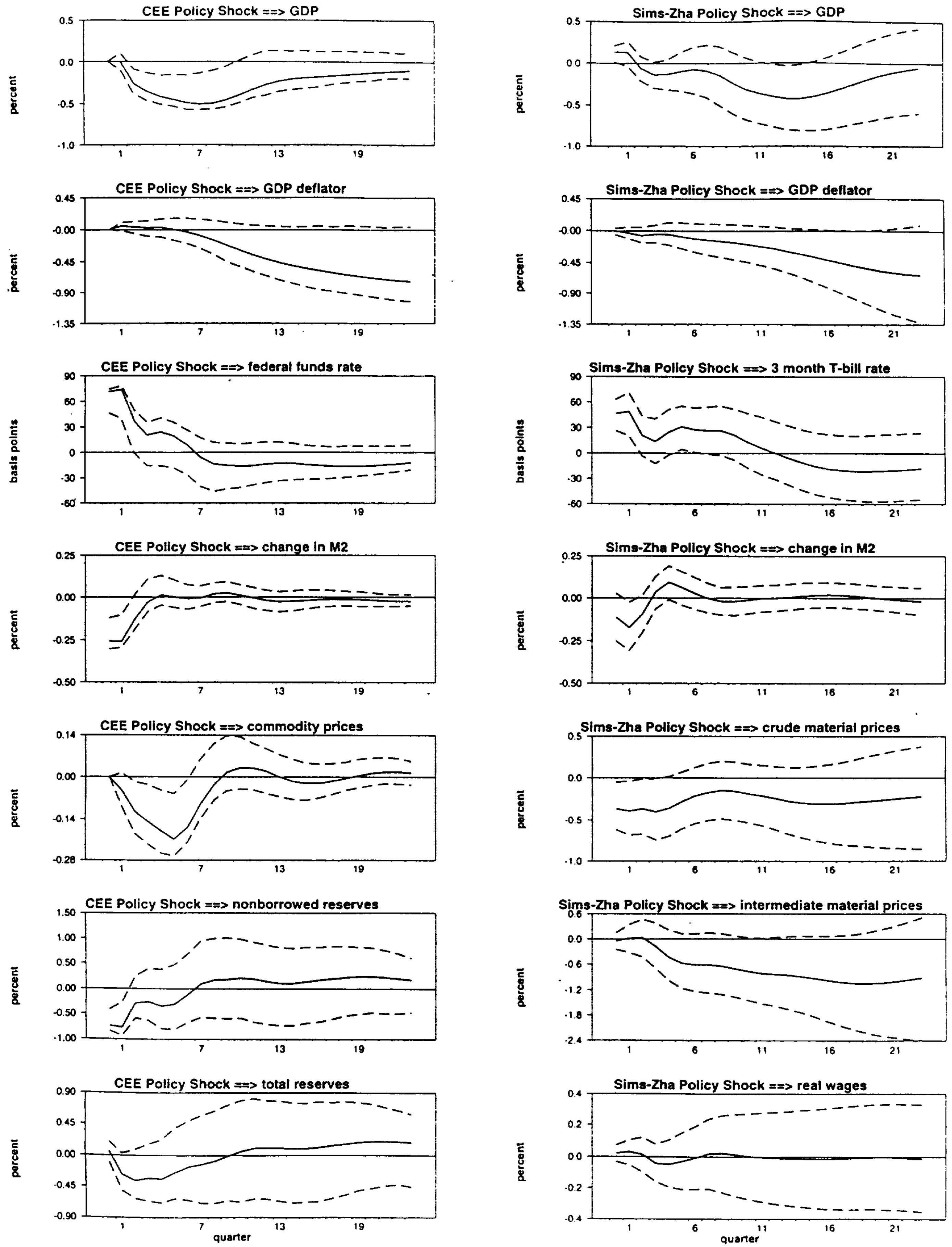

CEE Policy Shock ==> GDP
Sims-Zha Policy Shock ==> GDP
CEE Policy Shock ==> GDP deflator
Sims-Zha Policy Shock ==> GDP deflator
CEE Policy Shock ==> federal funds rate
Sims-Zha Policy Shock ==> 3 month T-bill rate
CEE Policy Shock ==> change in M2
Sims-Zha Policy Shock ==> change in M2
CEE Policy Shock ==> commodity prices
Sims-Zha Policy Shock ==> crude material prices
CEE Policy Shock ==> nonborrowed reserves
Sims-Zha Policy Shock ==> intermediate material prices
CEE Policy Shock ==> total reserves
Sims-Zha Policy Shock ==> real wages
percent
basis points
quarter

Figure 2

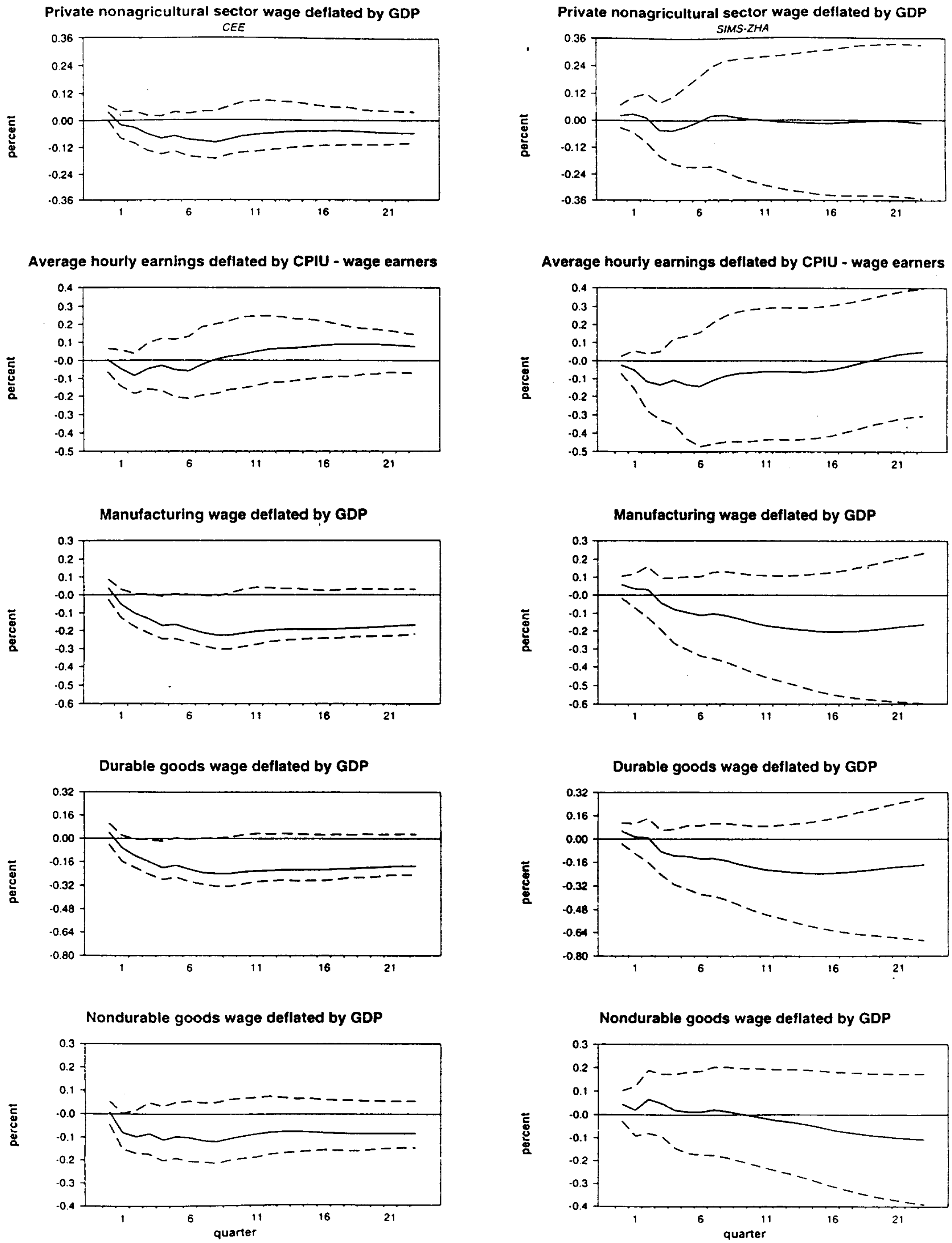
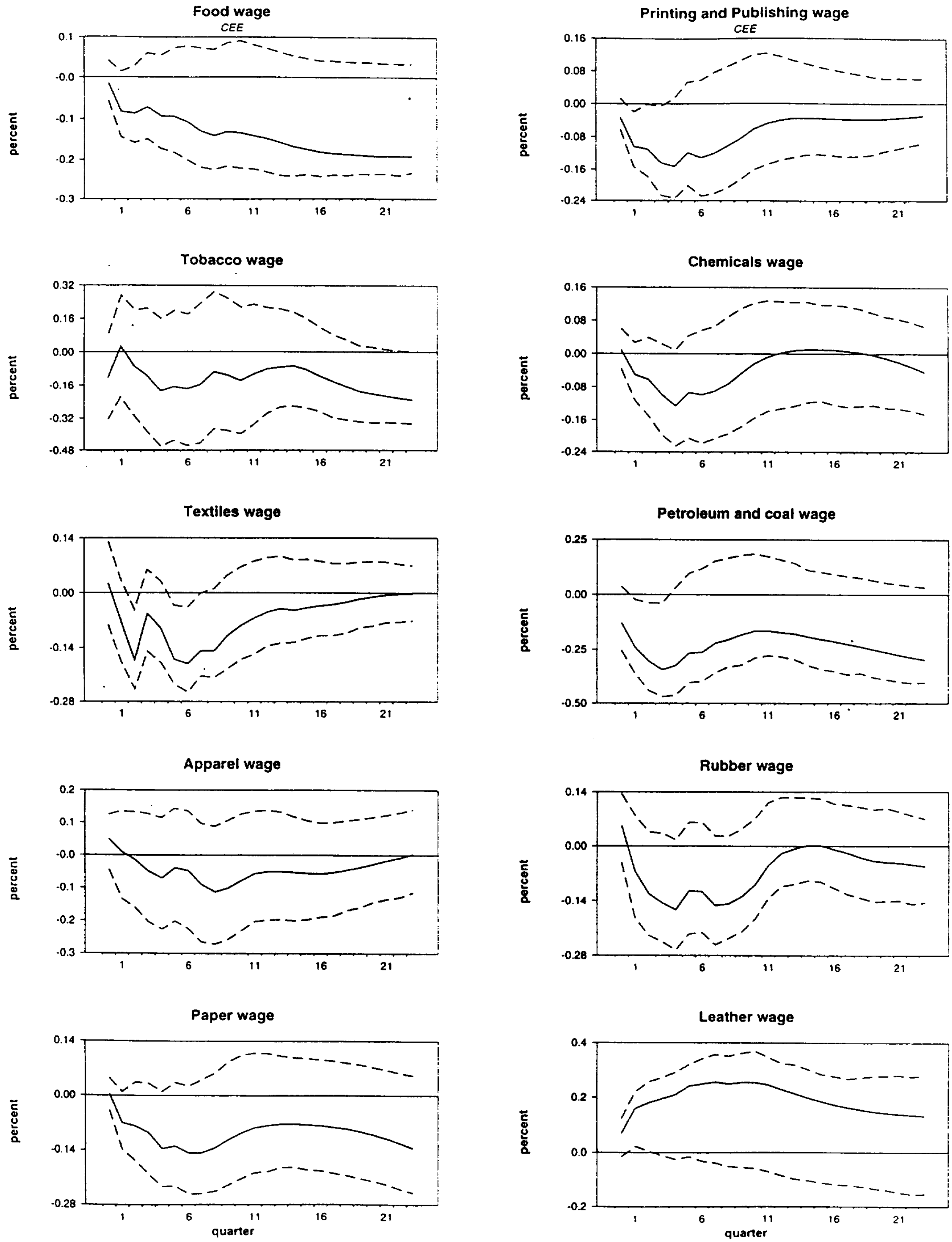

Private nonagricultural sector wage deflated by GDP
CEE
Private nonagricultural sector wage deflated by GDP
SIMS-ZHA
Average hourly earnings deflated by CPIU - wage earners
Average hourly earnings deflated by CPIU - wage earners
Manufacturing wage deflated by GDP
Manufacturing wage deflated by GDP
Durable goods wage deflated by GDP
Durable goods wage deflated by GDP
Nondurable goods wage deflated by GDP
Nondurable goods wage deflated by GDP
percent
quarter
1
6
11
16
21

Figure 3



Food wage
CEE
0.1
-0.0
-0.1
-0.2
-0.3
percent
1
6
11
16
21
Printing and Publishing wage
CEE
0.16
0.08
0.00
-0.08
-0.16
-0.24
percent
Tobacco wage
0.32
0.16
0.00
-0.16
-0.32
-0.48
percent
Chemicals wage
0.16
0.08
0.00
-0.08
-0.16
-0.24
percent
Textiles wage
0.14
0.00
-0.14
-0.28
percent
Petroleum and coal wage
0.25
0.00
-0.25
-0.50
percent
Apparel wage
0.2
0.1
-0.0
-0.1
-0.2
-0.3
percent
Rubber wage
0.14
0.00
-0.14
-0.28
percent
Paper wage
0.14
0.00
-0.14
-0.28
percent
quarter
Leather wage
0.4
0.2
0.0
-0.2
percent
quarter

Figure 4

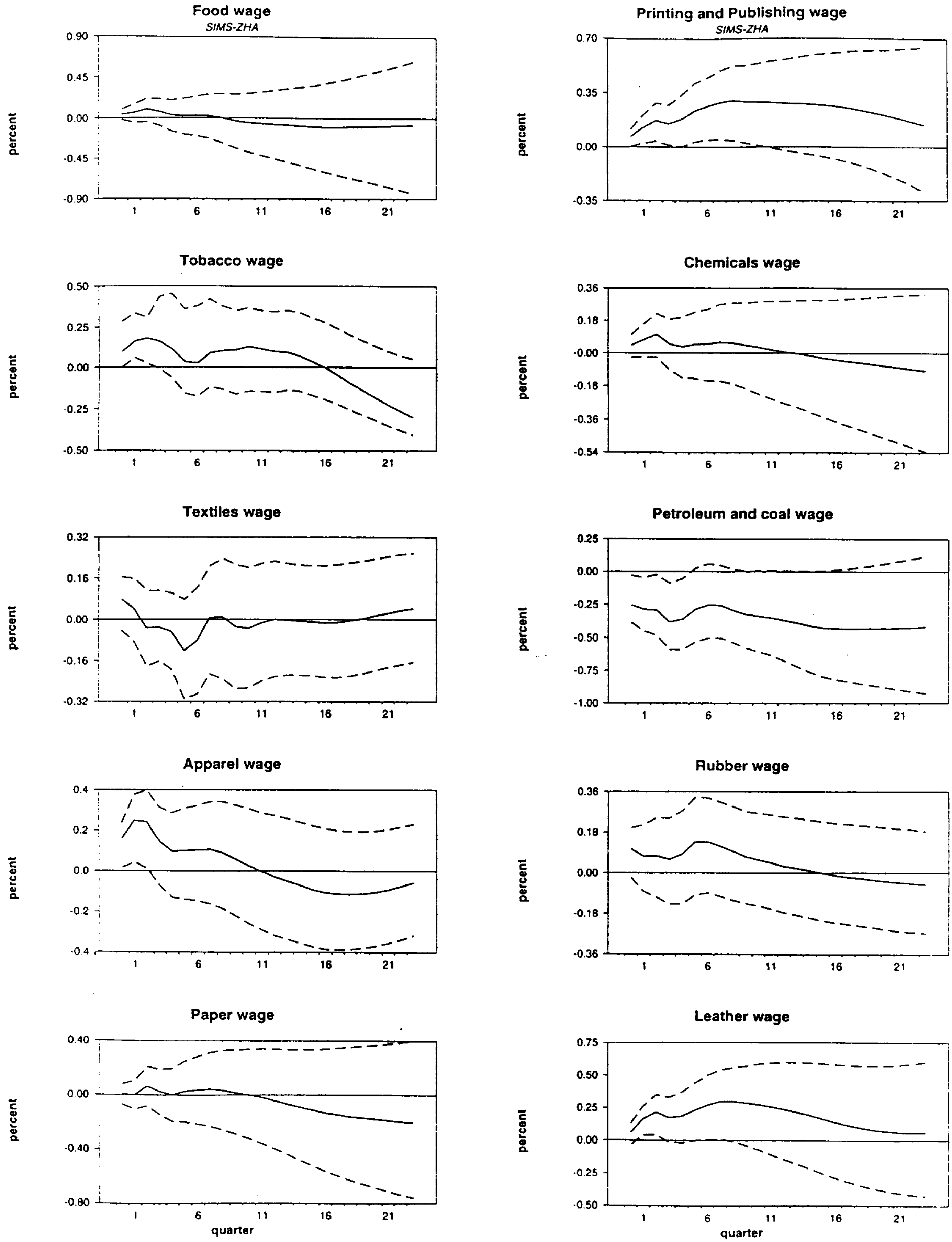
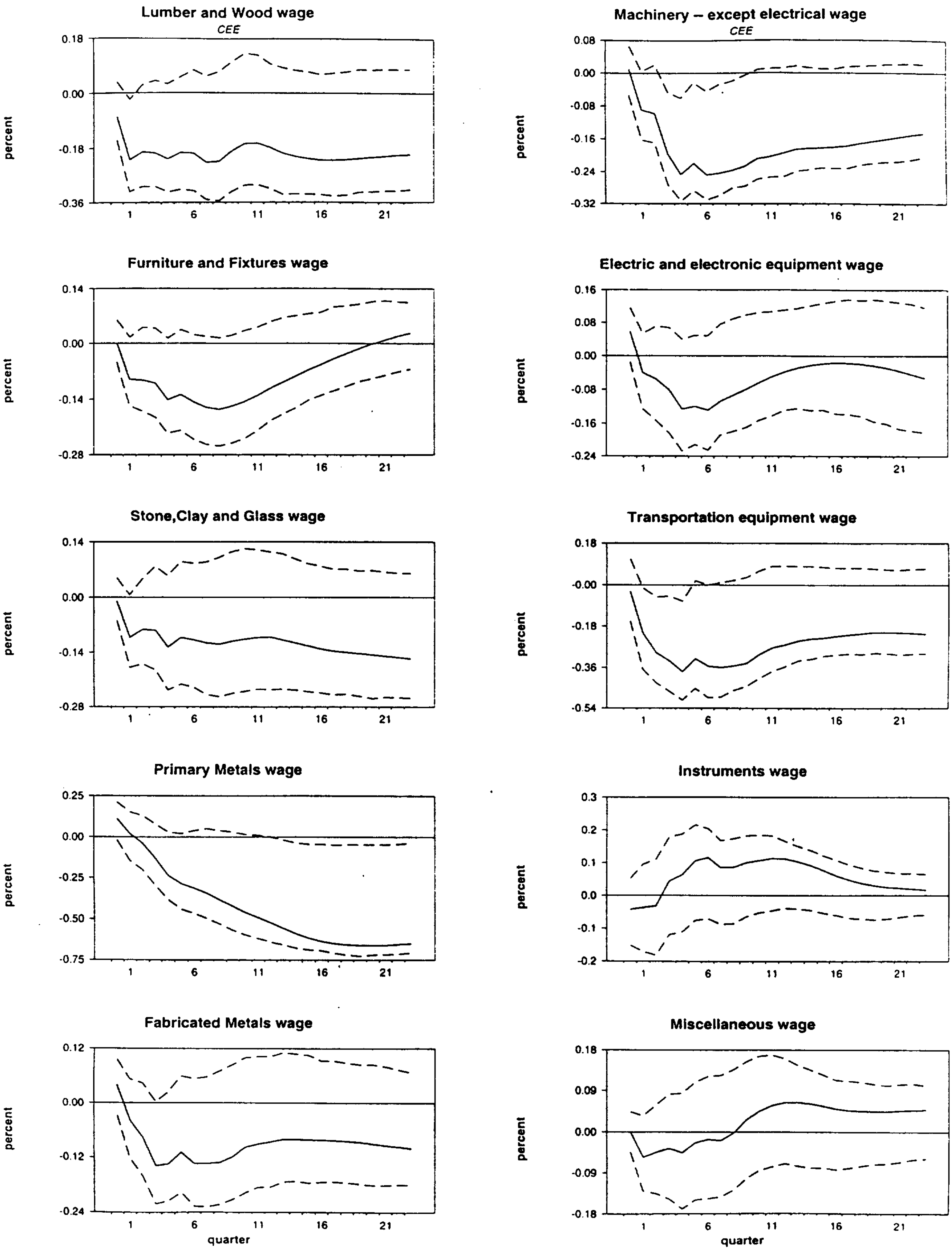

Food wage
SIMS-ZHA
0.90
0.45
0.00
-0.45
-0.90
percent
1
6
11
16
21
Printing and Publishing wage
SIMS-ZHA
0.70
0.35
0.00
-0.35
percent
Tobacco wage
0.50
0.25
0.00
-0.25
-0.50
Chemicals wage
0.36
0.18
-0.00
-0.18
-0.36
-0.54
Textiles wage
0.32
0.16
0.00
-0.16
-0.32
Petroleum and coal wage
0.25
0.00
-0.25
-0.50
-0.75
-1.00
Apparel wage
0.4
0.2
0.0
-0.2
-0.4
Rubber wage
0.36
0.18
0.00
-0.18
-0.36
Paper wage
0.40
0.00
-0.40
-0.80
quarter
Leather wage
0.75
0.50
0.25
0.00
-0.25
-0.50
quarter

Figure 5



Lumber and Wood wage
CEE
0.18
0.00
-0.18
-0.36
percent
Machinery -- except electrical wage
CEE
0.08
0.00
-0.08
-0.16
-0.24
-0.32
percent
Furniture and Fixtures wage
0.14
0.00
-0.14
-0.28
percent
Electric and electronic equipment wage
0.16
0.08
0.00
-0.08
-0.16
-0.24
percent
Stone,Clay and Glass wage
0.14
0.00
-0.14
-0.28
percent
Transportation equipment wage
0.18
-0.00
-0.18
-0.36
-0.54
percent
Primary Metals wage
0.25
0.00
-0.25
-0.50
-0.75
percent
Instruments wage
0.3
0.2
0.1
0.0
-0.1
-0.2
percent
Fabricated Metals wage
0.12
0.00
-0.12
-0.24
percent
Miscellaneous wage
0.18
0.09
0.00
-0.09
-0.18
percent
1
6
11
16
21
quarter

Figure 6

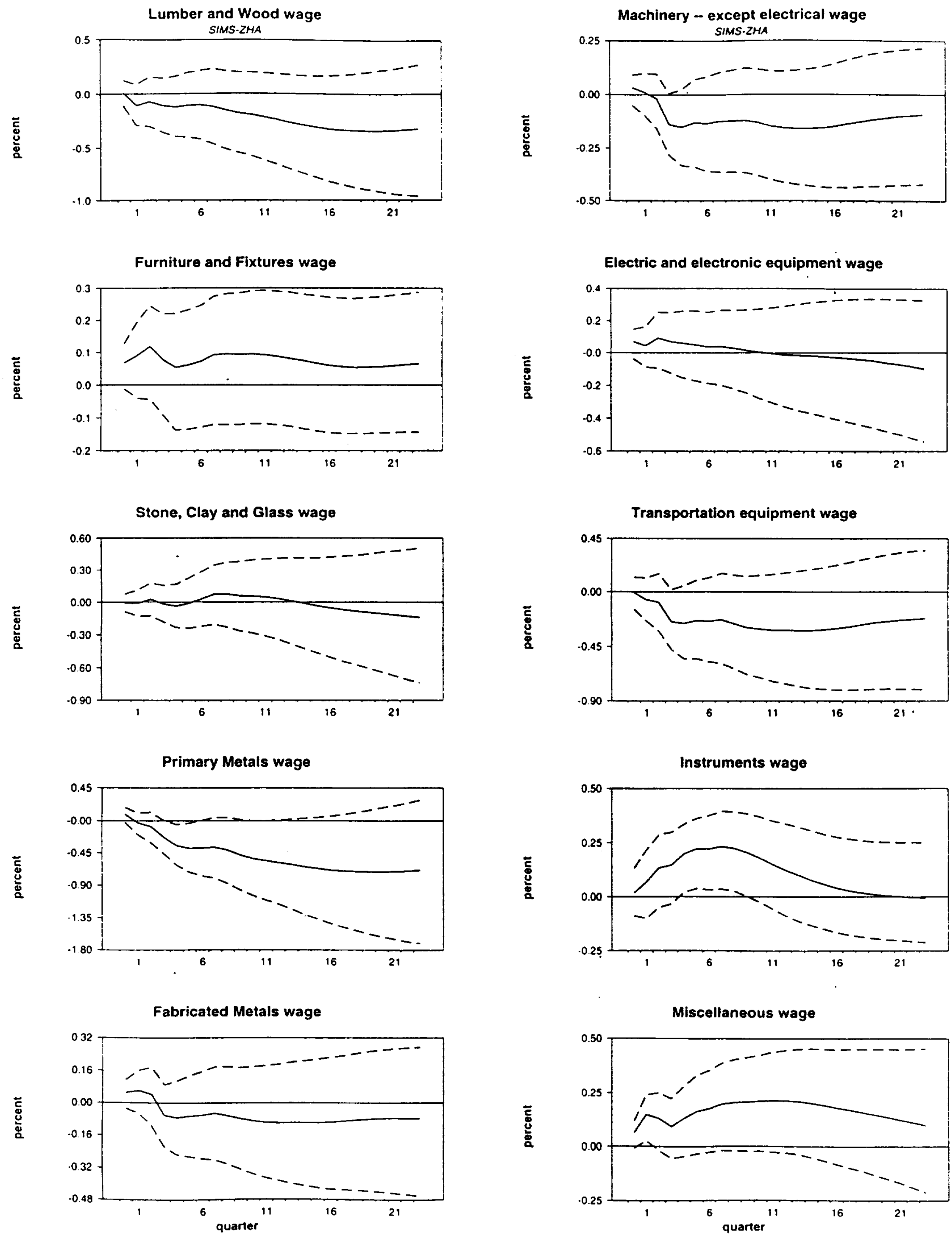
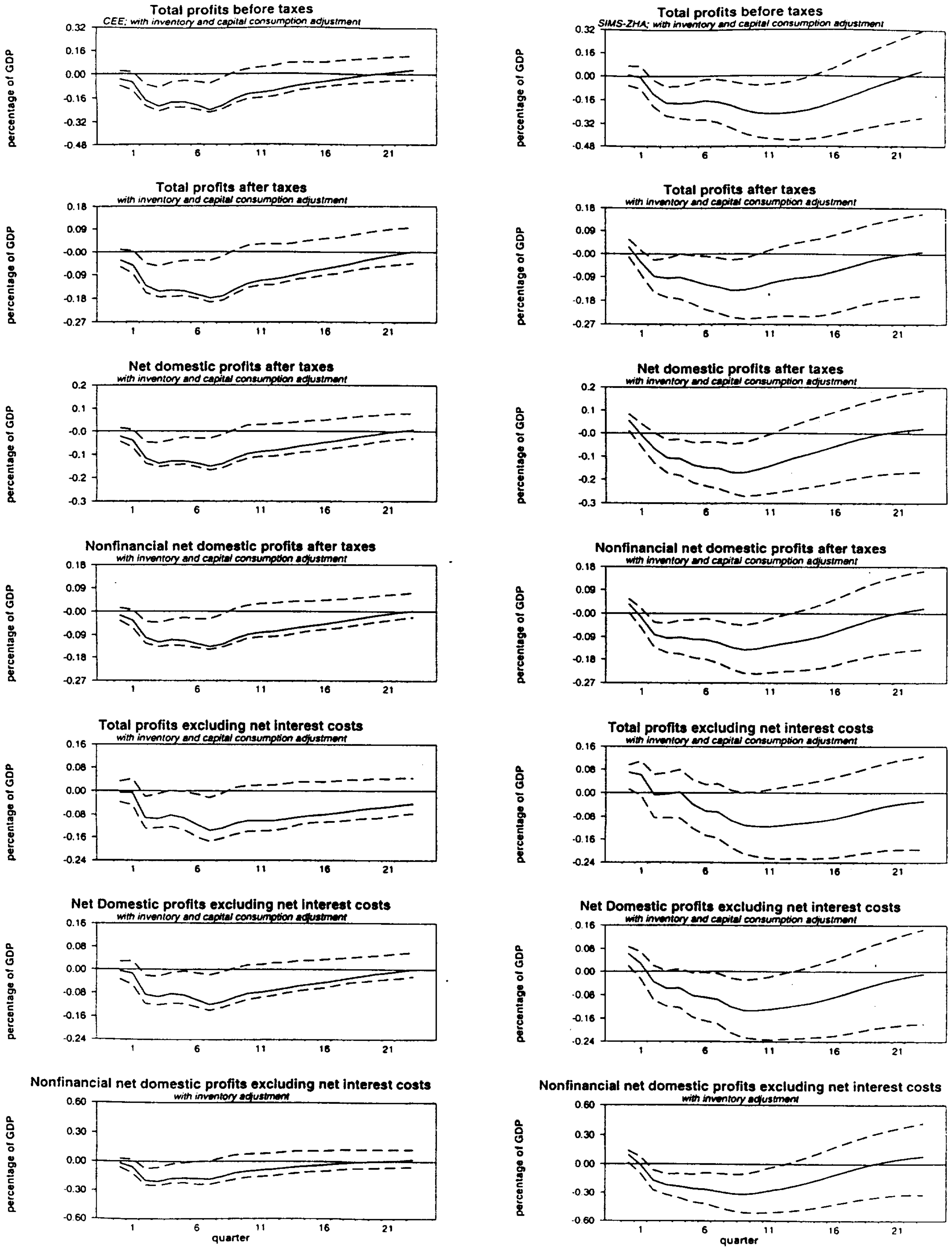
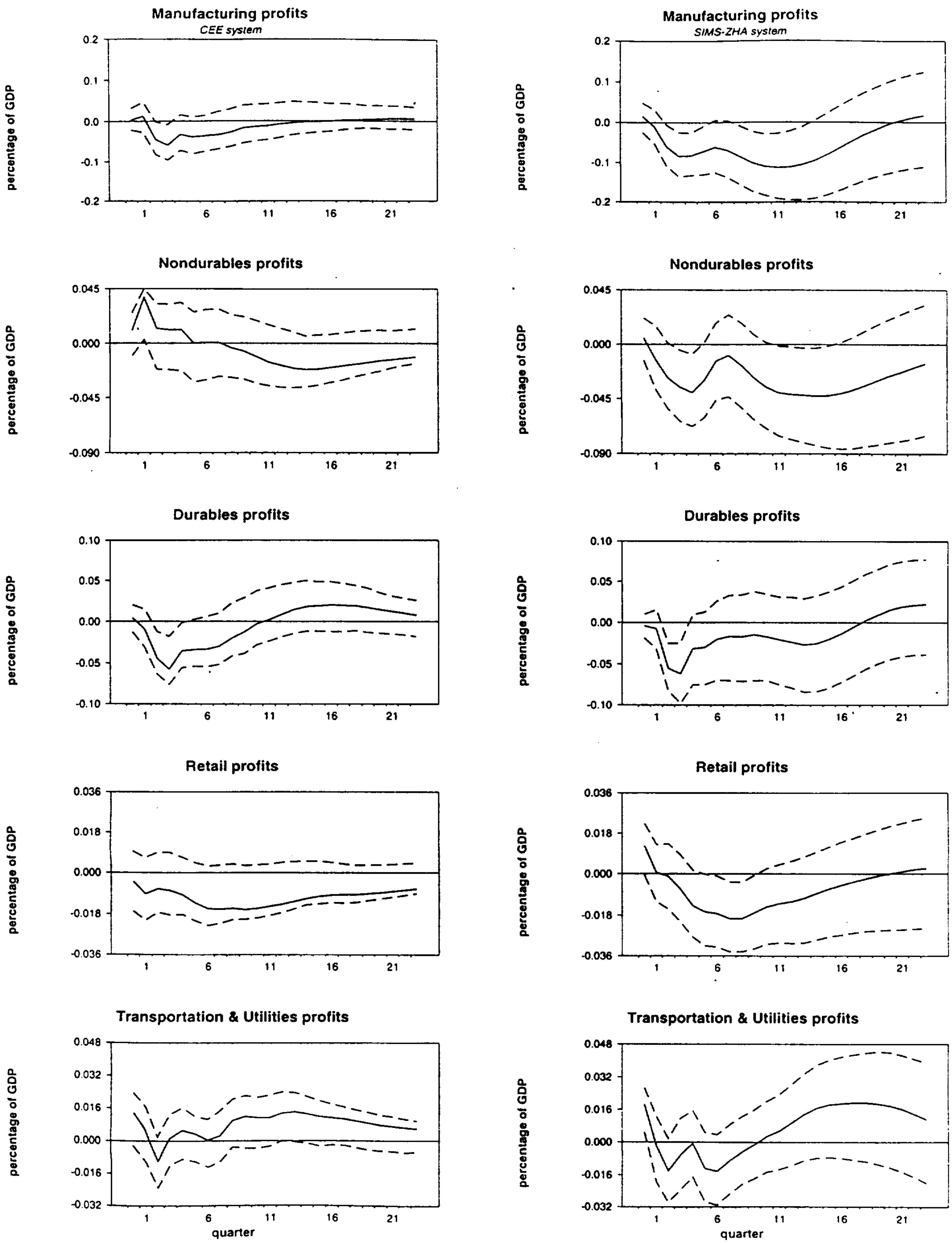

Lumber and Wood wage
SIMS-ZHA
0.5
0.0
-0.5
-1.0
percent
1
6
11
16
21
Machinery -- except electrical wage
SIMS-ZHA
0.25
0.00
-0.25
-0.50
percent
Furniture and Fixtures wage
0.3
0.2
0.1
0.0
-0.1
-0.2
Electric and electronic equipment wage
0.4
0.2
-0.0
-0.2
-0.4
-0.6
Stone, Clay and Glass wage
0.60
0.30
0.00
-0.30
-0.60
-0.90
Transportation equipment wage
0.45
0.00
-0.45
-0.90
Primary Metals wage
0.45
-0.00
-0.45
-0.90
-1.35
-1.80
Instruments wage
0.50
0.25
0.00
-0.25
Fabricated Metals wage
0.32
0.16
0.00
-0.16
-0.32
-0.48
quarter
Miscellaneous wage
0.50
0.25
0.00
-0.25
quarter

Figure 7

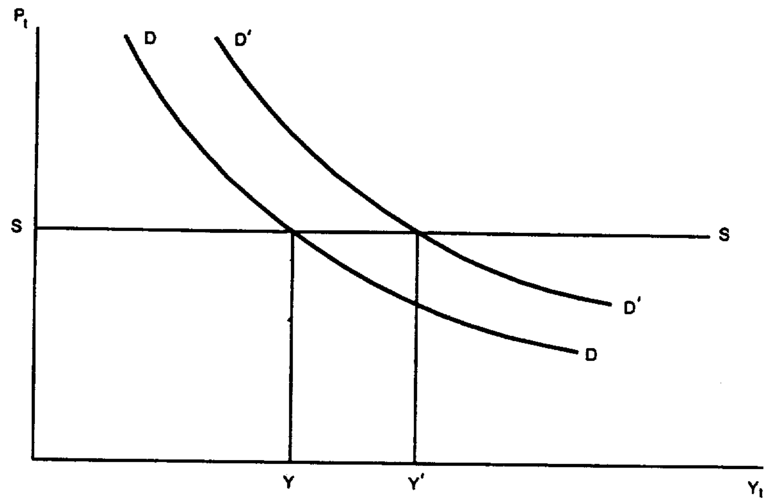


Total profits before taxes
CEE: with inventory and capital consumption adjustment
Total profits before taxes
SIMS-ZHA: with inventory and capital consumption adjustment
Total profits after taxes
with inventory and capital consumption adjustment
Total profits after taxes
with inventory and capital consumption adjustment
Net domestic profits after taxes
with inventory and capital consumption adjustment
Net domestic profits after taxes
with inventory and capital consumption adjustment
Nonfinancial net domestic profits after taxes
with inventory and capital consumption adjustment
Nonfinancial net domestic profits after taxes
with inventory and capital consumption adjustment
Total profits excluding net interest costs
with inventory and capital consumption adjustment
Total profits excluding net interest costs
with inventory and capital consumption adjustment
Net Domestic profits excluding net interest costs
with inventory and capital consumption adjustment
Net Domestic profits excluding net interest costs
with inventory and capital consumption adjustment
Nonfinancial net domestic profits excluding net interest costs
with inventory adjustment
Nonfinancial net domestic profits excluding net interest costs
with inventory adjustment
percentage of GDP
quarter

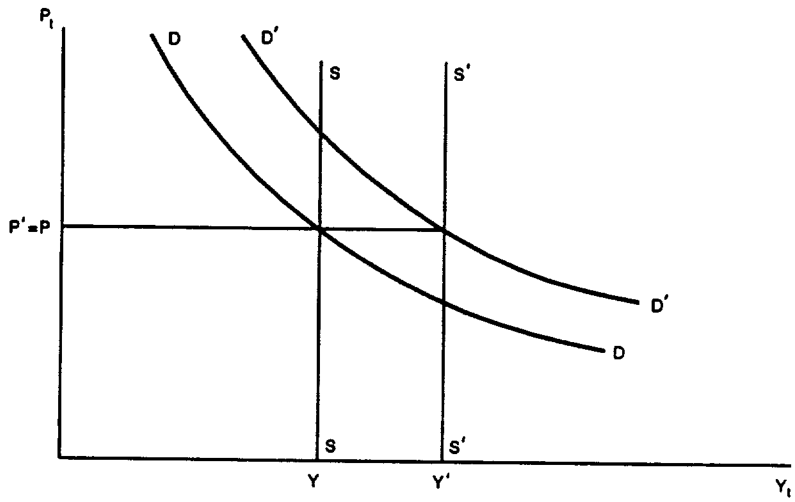
Figure 8


Manufacturing profits
CEE system
Manufacturing profits
SIMS-ZHA system
Nondurables profits
Nondurables profits
Durables profits
Durables profits
Retail profits
Retail profits
Transportation & Utilities profits
Transportation & Utilities profits
percentage of GDP
quarter
1
6
11
16
21
0.2
0.1
0.0
-0.1
-0.2
0.045
0.000
-0.045
-0.090
0.10
0.05
0.00
-0.05
-0.10
0.036
0.018
0.000
-0.018
-0.036
0.048
0.032
0.016
0.000
-0.016
-0.032

Graph 1
Equilibrium Price and Output in the Sticky Price Model



Graph 2
Equilibrium Price and Output in the Limited Participation Model



Graph 3
Equilibrium Real Wage and Employment in the Limited Participation Model

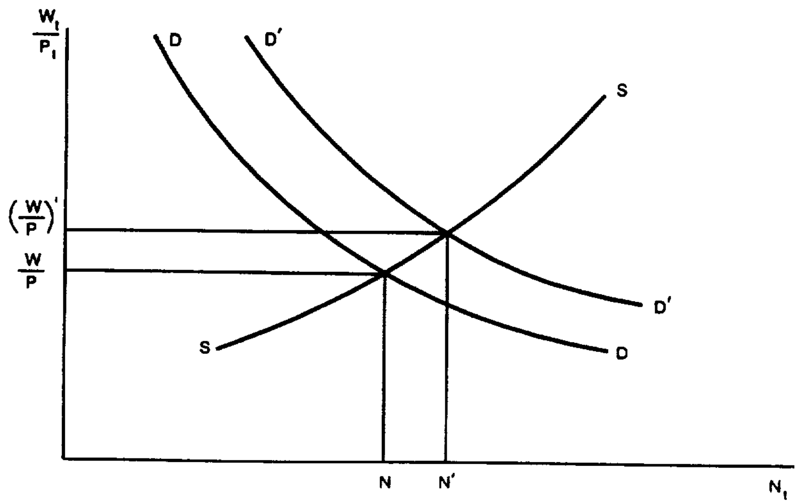


Table 1: Responses to a Monetary Contraction - Fixed Price Model								
	dp	dc	dn	dw	dMC	dR	χ	$d\pi$
	Panel A: Benchmark Parameter Values							
	0.00	−1.00	−1.30	−1.30	−2.54	−0.79	1.26	2.95
	Panel B: Different Labor Supply Elasticities							
$1/\psi = 0.1$	0.00	−1.00	−1.30	−12.99	−14.20	−0.75	1.64	15.94
$1/\psi = 0.5$	0.00	−1.00	−1.30	−2.60	−3.85	−.080	1.30	4.91
$1/\psi = 5$	0.00	−1.00	−1.30	−0.26	−1.44	−0.73	1.24	1.19
$1/\psi = 10$	0.00	−1.00	−1.30	−0.13	−1.29	−0.71	1.23	0.94
	Panel C: Different Markup Values							
$\mu = 1.01$	0.00	−1.00	−1.55	−1.55	−3.02	−0.93	1.07	3.92
$\mu = 1.20$	0.00	−1.00	−1.30	−1.30	−2.54	−0.79	1.26	2.95
$\mu = 1.40$	0.00	−1.00	−1.11	−1.11	−2.23	−0.73	1.46	2.26
$\mu = 2.00$	0.00	−1.00	−0.78	−0.78	−1.75	−0.71	2.07	1.15
	Panel D: Different Markup Values, Benchmark ϕ							
$\mu = 1.01$	0.00	−1.00	−1.30	−1.30	−2.70	−0.95	1.07	6.25
$\mu = 1.40$	0.00	−1.00	−1.30	−1.30	−2.43	−0.68	1.47	1.61
$\mu = 2.00$	0.00	−1.00	−1.30	−1.30	−2.25	−0.50	2.09	0.26
	Panel E: Miscellaneous							
$\alpha = 0$	0.00	−1.00	-0.83	−0.83	−1.56	−0.74	1.24	198.61
$\phi = 0$	0.00	−1.00	−1.56	−1.56	−2.85	−0.74	1.27	2.06
Modified Preferences, $\gamma = 1$	0.00	−1.00	−1.30	−2.30	−2.77	0.00	1.27	3.30
Modified Preferences, $\gamma = 2$	0.00	−1.00	−1.30	−3.30	−2.77	1.04	1.27	3.30
Modified Preferences, $\gamma = 2$ Persistent Shocks	0.00	−1.00	−1.30	−3.30	−2.77	1.04	1.27	3.30
	Panel F: Partial Price Setting							
80% Price Setters	−0.40	−0.60	−0.72	−0.72	−1.86	−0.48	1.24	1.25
20% Price Setters	−0.91	−0.09	−0.10	−0.10	−1.12	−0.08	1.21	−0.67

Table 2: Responses to a Monetary Contraction - Limited Participation Model							
	dp	dc	dn	dw	dMC	dR	$d\pi$
	Panel A: Benchmark Parameter Values						
	−0.62	−0.38	−0.50	−0.50	−0.62	0.70	−1.11
	Panel B: Different Labor Supply Elasticities						
$1/\psi = 0.1$	−0.95	−0.05	−0.06	−0.60	−0.95	0.64	−1.01
$1/\psi = 0.5$	−0.79	−0.21	−0.28	−0.55	−0.79	0.67	−1.06
$1/\psi = 5$	0.10	−1.10	−1.43	−0.29	0.10	0.83	−1.33
$1/\psi = 10$	0.43	−1.43	−1.86	−0.19	0.43	0.89	−1.43
	Panel C: Different Markup Values						
$\mu = 1.01$	−0.71	−0.29	−0.45	−0.45	−0.71	0.64	−1.01
$\mu = 1.20$	−0.62	−0.38	−0.50	−0.50	−0.62	0.70	−1.11
$\mu = 1.40$	−0.50	−0.50	−0.56	−0.56	−0.50	0.78	−1.26
$\mu = 1.40, 1/\psi = 2$	−0.08	−0.92	−1.02	−0.51	−0.08	0.91	−1.47
$\mu = 2.00$	0.11	−1.11	−0.86	−0.86	0.11	1.22	−2.00
$\mu = 2.00, 1/\psi = .5$	−0.54	−0.46	−0.36	−0.72	−0.54	0.87	−1.41
	Panel D: Different Markup Values, Benchmark ϕ						
$\mu = 1.01$	−0.78	−0.22	−0.29	−0.28	−0.78	0.40	−1.12
$\mu = 1.40$	−0.45	−0.55	−0.72	−0.72	−0.45	1.02	−1.11
$\mu = 2.00$	0.07	−1.07	−1.40	−1.40	0.07	1.98	−1.00
	Panel E: Miscellaneous						
$\alpha = 0$	−0.96	−0.04	−0.03	−0.03	−0.96	0.04	24.44
$\phi = 0$	−0.56	−0.44	−0.69	−0.69	−0.56	0.98	−1.00
Modified Preferences, $\gamma = 1$	−0.76	−0.24	−0.31	−0.54	−0.76	0.68	−1.07
Modified Preferences, $\gamma = 2$	−0.83	−0.17	−0.22	−0.56	−0.83	0.66	−1.05
ModifiedPreferences, $\gamma = 2$ Persistent shocks	−0.83	−0.17	−0.22	−0.56	−0.83	0.66	−1.05
	Panel F: Partial Price Setting						
80% Price Setters	−0.48	−0.52	−0.57	−0.57	−2.06	−0.81	1.35
20% Price Setters	−0.61	−0.39	−0.50	−0.50	−0.75	0.56	−0.87
	Panel G: Limited Intersectoral Mobility						
20% Price Setters	−0.53	−0.47	−0.59	−0.50	[1]	−0.64	0.14

[1]Marginal cost responses are not reported because they differ across the fixed and flexible price firms.