

Market Share Competition, Non-Separable Utility and the Propagation of Monetary Policy Shocks

by

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Abstract

I extend a standard monetary business cycles model with fully flexible prices along two dimensions: market share competition as proposed by Phelps and Winter (1970) and the assumption that the utility function of the representative household is non-additively separable in money and consumption. Market share competition makes the markups of prices over marginal costs endogenous which substantially improves the predictions of the model with respect to the propagation of monetary shocks. For a broad range of empirically plausible parameter values the impulse responses of output, employment and wages to these shocks display a one period delay and a substantial degree of persistence even when the monetary shock is serially uncorrelated. As a comparison between the standard New Keynesian model with Calvo pricing and the framework developed in this paper shows, the latter can be considered a useful alternative to the former for analyzing positive as well as normative issues.

JEL classification: E3, E4, E5

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1 Introduction

Christiano *et al.* (1999, 2005) provide empirical evidence indicating that positive monetary shocks are expansionary and induce highly persistent, hump-shaped dynamic responses of inflation, output, consumption and investment. Many economists try to explain this pattern by *New Keynesian* monetary business cycles models in which a very high degree of exogenously given price stickiness (e.g. of the Calvo-type) is combined with a whole battery of real rigidities and additional structural assumptions¹ as well as various *exotic* shocks.² Examples are Christiano *et al.* (2005), Walsh (2005), Trigari (2004), Altig *et al.* (2005), Smets and Wouters (2003, 2007) and many others. Most of these extensions are subject to debate. Such New Keynesian models are extensively used to evaluate monetary and fiscal policy as well as to derive normative conclusions and suggestions on how monetary policy should be conducted. Unfortunately, most of these models perform rather poorly with respect to phenomena other than the impulse responses to monetary innovations such as the sample moments at business cycle frequencies of many macroeconomic variables or the reactions to real supply side shocks. Another major disadvantage of the New Keynesian models is the lack of microeconomic foundation and thus, the lack of endogenous explanation of their most crucial component - the high degree of price rigidity (see Caplin and Spulber (1993), Golosov and Lucas (2007), Kehoe and Midrigan (2008)). The problem becomes even more severe in the light of the most recent micro evidence provided by Bils and Klenow (2004) and Klenow and Kryvstov (2005) indicating that nominal prices are

¹For example backward indexation of the prices of the non-adjusting firms, Calvo-type nominal wage setting, adjustment costs of capital and labor, habit persistence in consumption, matching frictions and job destruction in the labor market and even bounded rationality of part of the firms.

²For example different kinds of preference shocks, wage-markup and price-markup shocks, investment-specific shocks and even risk-premium shocks.

quite flexible, remaining unchanged for slightly more than one quarter on average. Calibrating the New Keynesian model so that it is consistent with these empirical findings leads to a dramatic worsening of its predictions: the degree of monetary nonneutrality falls sharply, the persistence and the hump-shape of the impulse responses to monetary innovations (almost completely) disappear and the markups of prices over marginal costs (*price markups*) become procyclical. These and other³ shortcomings cast doubt on the appropriateness of the sticky price models for analyzing normative issues.

The goal of the current paper is to propose an alternative theoretical framework for addressing the question of the propagation of business cycles shocks as well as that of explaining a set stylized business cycles facts. In particular, the model developed here should be immune to the critique of Caplin and Spulber (1993), Golosov and Lucas (2007) and Kehoe and Midrigan (2008) but at the same time it should perform at least as good as a typical New Keynesian model with a high degree of price stickiness. To achieve this, I employ an otherwise standard monetary business cycles model with fully flexible prices incorporating two "*novel*" features. First, monetary *nonneutrality* is introduced through the assumption that the utility function of the representative household is non-separable in money and consumption. Second, the monopolistically competitive firms do not only engage in static price competition but also in a form of dynamic market share competition. The latter is modeled in the way proposed by Phelps and Winter (1970).

The intrinsic forces propagating nominal shocks in the *baseline* model, assuming only non-separability of the utility function, are pretty weak and lead to predictions which are in many respects counterfactual. In particular, monetary expansions induce a contraction in hours, production and consumption. But extending the model by introducing market share competition in

³See for example Chari *et al.* (2008).

the goods market as proposed by Phelps and Winter (1970) and thus, making the markups of prices over marginal costs endogenous, substantially alters the qualitative as well as quantitative predictions of the model. In particular, for a broad range of empirically plausible values of the short run price elasticity of demand, the average markup and the degree of flexibility of capital accumulation the non-neutrality of money can be made arbitrarily strong. Furthermore, in that cases the model implies impulse responses of output, employment and wages displaying a one period delay and a substantial degree of persistence. It is important to note that the model developed in this paper assumes fully flexible prices and thus, is immune to the critique of Caplin and Spulber (1993) and Golosov and Lucas (2007) and at the same time it is not inconsistent with the evidence of Bils and Klenow (2004) and Klenow and Kryvstov (2005).

What are the main mechanisms at work in the model developed here? If the current utility function of the representative household in an otherwise standard monetary business cycles model is non-additively separable in money and consumption, and is given by the following CES-aggregator:

$$\left(aC_t^{1-b} + (1-a) \left(\frac{M_t}{P_t} \right)^{1-b} \right)^{\frac{1}{1-b}}, \quad a \in (0, 1), \quad b > 0,$$

where C , M and P denote consumption, nominal cash balances and the price level respectively, then monetary *expansions* tend to be *contractionary*. They induce a sharp increase in current inflation which reduces the marginal utility of consumption "today" relative to its value in the future. The result is a relatively large negative deviation of labor supply and thus, of output and consumption in the period of the shock. Only in the case of a very high degree of flexibility of capital accumulation these variables reach above average values in the period after the shock. Otherwise, they return almost immediately, from below, to their respective long run levels. Such a prediction is counterfactual. But the disturbance of the time path of the marginal utility of consumption just

described implies an increase in the stochastic discount factor which in turn implies an increase in the present value of firms' future profits. If the goods market is characterized by the usual static monopolistic competition, future profits don't matter for the current pricing decisions of the typical firm. But if the environment has the structure suggested by Phelps and Winter (1970), future profits become a crucial determinant of firms' behavior. If the expected present value of future revenues increases relative to their current level, each firm will have an incentive to make additional "*investments*" in its future market share by lowering its current price and thus, by lowering its current markup. The decrease in markups will have a positive effect on the real wage and thus, on the labor supply decision made by households. As a result, in the economy characterized by market share competition employment, consumption and output will tend to be procyclical or at least less countercyclical than in the case of static monopolistic competition. As shown below, the lower the short run price elasticity of demand and the higher the steady state markup, the larger the fall in markups and thus, the more pronounced the increase in real wages, employment, and output. The persistence generated by the model is due to the interaction between capital accumulation and markup fluctuations and is described in sections 6 and 7.

The paper is organized as follows. In section 2 I provide a short review of the empirical evidence and the related literature respectively. Section 3 motivates the key assumptions of the model - non-separability of the utility function and market share competition. Section 4 describes the baseline monetary model without capital accumulation while section 5 extends it by the assumption of market share competition in the goods market. Capital accumulation and adjustment costs of capital are introduced in sections 6 and 7. In section 8 I evaluate the performance of the model with adjustment costs of capital with respect to a subset of stylized business cycles facts and compare it

with the performance of the New Keynesian Model with Calvo pricing. Section 9 concludes.

2 Review of the Literature

2.1 Empirical Evidence

Observable Reactions to Monetary Shocks: The VAR-evidence provided by Sims (1980, 1986), Gertler and Gilchrist (1994), Cochrane (1994), Christiano *et al.* (1999, 2005), Altig *et al.* (2005), Biovin and Giannoni (2008) and many others indicates that there are delayed, hump-shaped dynamic responses of output, consumption, investment and inflation to monetary disturbances, characterized by a substantial degree of persistence with all four variables remaining above their respective initial values for about twelve quarters. The peak-responses of these variables equal about 0.4%, 0.1%, 1% and 0.1% respectively. To at least partly reproduce the shape and persistence of these impulse responses is of major concern to modern monetary economics.

The Importance of the Cyclical Behavior of Markups: In a comprehensive survey of the empirical studies on the cyclical behavior of prices and marginal costs Rotemberg and Woodford (1999) emphasized the great importance of markups for output fluctuations at business cycle frequencies. According to their results, the output fluctuations attributable to variations of markups, which are orthogonal to fluctuations induced by shifts in the marginal cost curve, account for about 90% of the variance of output growth in the short run.⁴ In addition, it can be easily shown that endogenous markup variation

⁴Rotemberg and Woodford (1999) decompose output into two components. The fluctuations of the first result solely from shifts in the marginal cost curve for a constant markup while the second component responds only to deviations of markups from their steady state values, and hence represents movements along the marginal cost curve. Rotemberg and

on the aggregate level has the potential to substantially magnify (or dampen) business cycles or make them more (or less) persistent.⁵ Rotemberg and Woodford (1999) base their estimation on functions of labor share, controlling for variable utilization rates, overhead labor and wages for overtime hours. The authors conclude that markups are negatively correlated with output⁶ and respond negatively to demand as well as supply side shocks. Boldrin and Horvath (1996), Gomme and Greenwood (1995), Ambler and Cardia (1996) and Gali *et al.* (2002) also obtain negative estimates of the correlation between output and markups. Also related to the short run fluctuations of marginal costs and markups is the VAR evidence provided by Christiano *et al.* (1999, 2005) and others. They show that an expansionary monetary shock induces an increase in employment⁷ and real wages. But if capital is fixed in the short run and there is diminishing marginal product of labor the positive response of employment can be associated with higher real wages only if markups fall. Hence, the impulse responses estimated by Christiano *et al.* can be seen as evidence supporting the findings of Rotemberg and Woodford (1999) about the importance of markup variations as well as their cyclical properties.

2.2 Related Theoretical Studies

The purpose of this subsection is to provide a brief review of the literature attempting to develop an alternative to the widely used New Keynesian model with Calvo pricing as well as the most important studies focusing on markup

Woodford (1999) use the *predicted declines of output* as measure of the cyclical component of output and compare it with the two components of output growth they identify.

⁵Rotemberg and Woodford (1999) provide a simple example.

⁶According to their estimates the correlation between output and markups lies between -0.188 and -0.273.

⁷In fact, Christiano *et al.* (1999, 2005) estimate the impulse responses of output to monetary shocks. But, as capital is a predetermined state variable, increases in output can occur only if hours increase.

variations.

Endogenous Price Rigidity:

Haubrich and King (1991) develop a model in which firms are able to insure against idiosyncratic monetary shocks by signing nominal contracts. However, as the authors point out, the price-rigidity equilibrium is only one of the possible outcomes under the specific assumptions on the parameters made. The parameterization of their model, too, is only one of many plausible ones. Nakamura and Stensson (2007) construct a model with good-specific habit persistence in which price stickiness arises as an equilibrium outcome. However, there are again many further equilibria characterized by fully flexible prices. In addition, the results in Nakamura and Steinsson (2007) should be interpreted with caution because they are derived within a partial equilibrium framework. The *sticky-information* literature proposes an approach slightly different from that adopted in the Calvo model. The former assumes that nominal prices are fully flexible but the flow of information to private agents is not. In particular, each firm faces a constant probability per period to be able to obtain the most recent information about the state of the economy. In other words, the sticky-information models replace the Calvo-type price setting by a Calvo-type updating of information. Examples are Mankiw and Reis (2001, 2006a, 2006b), Ball *et al.* (2003) and others. A major shortcoming of this framework is the fact that the process of updating information is exogenous and lacks a microeconomic foundation. The *menu-cost* models⁸ generate monetary nonneutrality by assuming that there are small fixed costs of adjusting prices. However, as Bursten and Hellwig (2007) argue, to generate strong and persistent effects of monetary policy, these models need parameter values which are inconsistent with the micro evidence on the level of menu costs and the typical magnitude

⁸See for example Caplin and Spulber (1993), Golosov and Lucas (2007), Burstein and Hellwig (2007), Gertler and Leahy (2006), Gorodnichenko (2008) and others.

of price adjustments.

Real Business Cycles Models of Endogenous Markups:

In the already cited study by Phelps and Winter (1970) markups are endogenized by the assumption of a particular form of dynamic market share competition in continuous time. The discrete time version of that structure is used in the model presented below. In a series of real business cycles models based on the partial equilibrium model proposed by Rotemberg and Saloner (1986), Rotemberg and Woodford⁹ show that endogenous markup variations may arise if firms are able to collude implicitly. Ravn *et al.* (2006, 2007) are able to generate countercyclical markups by introducing good-specific habit formation, the so called *deep habits*, into a standard RBC-model with a monopolistically competitive goods market. Froot and Klemperer (1989), Klemperer (1987, 1995) and Kleshchelski and Vincent (2007) develop static models of the goods market in which customers face fixed costs of switching suppliers. All these models have in common the implication that firm's current pricing behavior has an influence on its future profits. Since the studies just mentioned neglect the money market, they do not provide any implications about the reactions of markups to monetary shocks.

3 The Key Assumptions

3.1 Non-Separable Utility

The monetary general equilibrium models developed in the last ten years usually assume that the utility function of the representative agent is *separable*

⁹Rotemberg and Woodford (1992), (1995), (1996)

with respect to money and consumption, e.g.

$$\frac{C_t^{1-\eta}}{1-\eta} + \frac{\phi}{1-\chi} \left(\frac{M_t}{P_t} \right)^{1-\chi}, \quad \text{for } 0 < \eta, \chi \neq 1, \quad \phi > 0,$$

$$\ln(C_t) + \tilde{\phi} \ln \left(\frac{M_t}{P_t} \right), \quad \text{for } \eta = \chi = 1, \quad \tilde{\phi} > 0.$$

Nonetheless, it is quite well known that almost all *separable* specifications are just special cases of more general *non-separable*, (nested¹⁰) Cobb-Douglas or CES¹¹ aggregators combining consumption and real balances. Furthermore, economic theory does not provide any convincing reason for preferring the separable to the non-separable formulation *et vice versa*. The only comparative advantage of the former is perhaps its analytical simplicity. Indeed, in his seminal paper Sidrauski (1967) assumes that money and consumption enter the utility function non-separably, through a Cobb-Douglas aggregator. The early literature inspired by Sidrauski (1967), e.g. Brock (1974, 1975), Fisher (1979), Asako (1983) and others, dealing with the stability and the steady state properties of monetary general equilibrium models, also consider the non-separable utility function to be more important while the separable specification is only treated as a special case.

Finally, the empirical evidence supports the assumption that utility is non-separable in consumption and real balances: in a more recent study Holman (1998) performs a GMM estimation of the Euler equation for optimal money holdings under different specifications of the utility function - Cobb-Douglas,

¹⁰The nested Cobb-Douglas specification of the utility function is given by:

$$\frac{\left(C_t^\alpha \left(\frac{M_t}{P_t} \right)^{1-\alpha} \right)^{1-\rho}}{1-\rho}, \quad \alpha \in (0, 1), \quad \rho > 0,$$

while the non-nested case is obtained by setting $\rho = 0$.

¹¹CES - Constant Elasticity of Substitution.

CES and nested Cobb-Douglas or CES.¹² Based on a series of tests the author rejects the separable form while the Cobb-Douglas, the CES (used here) and the nested CES formulation can not be rejected. The quasi-likelihood-ratio tests employed indicate that the non-nested Cobb-Douglas specification performs slightly better than the other ones.

All in all, the assumption that the utility function is non-separable in money and consumption seems to be at least as plausible as the opposite one. At the same time, the non-nested CES specification chosen in the current paper, although arbitrary, is not rejected by the data.

3.2 Market Share Competition

Phelps and Winter (1970) depart from the frictionless specification of the goods market by assuming that customers can not respond instantaneously to differences in firm specific prices. As the authors note, there are various rationales for this assumption - information imperfections, habits as well as costs of decision-making, none of which is explicitly modeled in their paper. An immediate consequence of such frictions is that in the (very) short run each firm has some monopoly power over a fraction of all consumers. This fraction equals the firm's market share. In particular, Phelps and Winter (1970) assume that the transmission of information about prices evolves (proceeds) through random encounters among customers in which they compare recent demand experience. Under this assumption the probability with which a comparison between any two firms i and j is made will be approximately proportional to the product of their respective market shares x_i and x_j . Therefore, one would

¹²The nested CES specification of the utility function is given by:

$$\frac{\left(aC_t^{1-b} + (1-a) \left(\frac{M_t}{P_t} \right)^{1-b} \right)^{\frac{1-\rho}{1-b}}}{1-\rho}, \quad a \in (0,1), \quad b, \rho > 0,$$

while the non-nested case is obtained by setting $\rho = 0$.

expect that the time rate of net customer flow from firm j to firm i will also be proportional to the product $x_i x_j$. Phelps and Winter formalize this as follows:

$$z_{i,j} = \delta(p_i, p_j) x_i x_j,$$

where $z_{i,j}$ is the net flow of customers from j to i . The function $\delta(p_i, p_j)$ has the properties:

$$\text{sgn}(\delta(p_i, p_j)) = \text{sgn}(p_j - p_i), \quad \delta(p_i, p_j) = -\delta(p_j, p_i), \quad \delta_1 < 0, \quad \delta_2 > 0.$$

The market share x_i then evolves according to:

$$\dot{x}_i = \sum_{j=1}^m z_{i,j} = x_i \sum_{j=1}^m \delta(p_i, p_j) x_j = x_i \sum_{j=1, j \neq i}^m \delta(p_i, p_j) x_j,$$

where m is the number of firms. Defining the customer-weighted mean of other firms' prices \bar{p}_i by

$$\bar{p}_i = \frac{\sum_{j \neq i}^m p_j x_j}{\sum_{j \neq i}^m x_j} = \frac{\sum_{j \neq i}^m p_j x_j}{1 - x_i}$$

and expanding $\delta(p_i, p_j)$, $\forall j \neq i$ in a first order Taylor's series with respect to its second argument one obtains:¹³

$$\dot{x}_i \approx x_i(1-x_i)\delta(p_i, \bar{p}_i) + x_i \delta_2(p_i, \bar{p}_i) \left(\underbrace{\sum_{j \neq i}^m p_j x_j}_{:= \bar{p}_i(1-x_i)} - \bar{p}_i(1-x_i) \right) = x_i(1-x_i)\delta(p_i, \bar{p}_i).$$

Assuming that each supplier is small enough, so that the following relations hold:

$$1 - x_i \approx 1 \quad \Rightarrow \quad \bar{p}_i \approx \sum_{j \neq i}^m p_j x_j = \bar{p},$$

¹³Actually, Phelps and Winter approximate $\delta(p_i, p_j)$ by a second order Taylor's series but then assume that the second order terms are negligible and drop them. Consequently, their results are identical with that delivered in this section.

where \bar{p} is the overall mean price in the goods market, the law of motion of x_i reduces to

$$\dot{x}_i \approx \delta(p_i, \bar{p})x_i. \quad (1)$$

The discrete-time version of (1) used in the following sections reads:

$$x_{i,t+1} = g\left(\frac{p_{i,t}}{\bar{p}_t}\right)x_{i,t},$$

where $\delta(p_{i,t}, \bar{p}_t) = g\left(\frac{p_{i,t}}{\bar{p}_t}\right) - 1$.¹⁴ Now assume that the demand of each individual belonging to the customer stock of firm i is given by $D\left(\frac{p_{i,t}}{\bar{p}_t}\right)$. Then the *demand curve* faced by firm i is given by:

$$x_{i,t}D\left(\frac{p_{i,t}}{\bar{p}_t}\right) = g\left(\frac{p_{i,t-1}}{\bar{p}_{t-1}}\right)x_{i,t-1}D\left(\frac{p_{i,t}}{\bar{p}_t}\right).$$

Hence, the price setting problem of the typical firm becomes dynamic.

4 A Model with Fixed Capital and Static Monopolistic Competition (No Market Share Competition)

This section provides a short sketch of the baseline *Money in the Utility Function Model*.

¹⁴To see that, write the discrete-time version of (1) in the more general form

$$x_{i,t} - x_{i,t-h} = \left(g\left(\frac{p_{i,t}}{\bar{p}_t}\right) - 1\right)h \cdot x_{i,t-h},$$

where $\left(g\left(\frac{p_{i,t}}{\bar{p}_t}\right) - 1\right)h$ measures the net customer flow to firm i over a time interval of length h . Divide both sides of the last equation by h , let h go to zero and assume that $x_{i,t}$ is differentiable from the left (from below) with respect to t . The resulting equation is:

$$\dot{x}_{i,t} = \left(g\left(\frac{p_{i,t}}{\bar{p}_t}\right) - 1\right)x_{i,t}.$$

4.1 The Theoretical Framework

4.1.1 Firms

There are n product varieties, each produced by a profit maximizing monopolistic firm according to the linear production function

$$Y_{i,t} = Z_t N_{i,t},$$

where $N_{i,t}$ denotes labor input of firm i . Z_t denotes the total factor productivity which follows a stochastic process given by:

$$\ln(Z_t) = \rho_z \ln(Z_{t-1}) + \epsilon_t,$$

where ϵ_t follows a *White Noise Process* with variance σ_ϵ^2 .

The demand function faced by the producer of variety i is given by

$$C_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\theta} \cdot \frac{C_t}{n}, \quad \theta > 0, \quad (2)$$

where C_t denotes aggregate consumption expenditure.

The profit maximizing relative price satisfies the equation

$$\frac{P_{i,t}}{P_t} = \frac{\theta}{\theta - 1} \frac{W_t/P_t}{Z_t},$$

where $\frac{W_t}{P_t}$ denotes the real wage and $mu = \frac{\theta}{\theta-1}$ the markup.

4.1.2 Households

Let agents in this economy have preferences over consumption, real balances and working hours given by

$$U = E_t \left\{ \sum_{t=0}^{\infty} \beta^t \left(\left(a C_t^{1-b} + (1-a) \left(\frac{M_t}{P_t} \right)^{1-b} \right)^{\frac{1}{1-b}} - \frac{\phi}{2} N_t^2 \right) \right\}, \quad \phi, b > 0, \quad \beta, a \in (0, 1),$$

where M_t/P_t and N_t denote real balances and working hours. In the above expression C_t is a composite good that includes all varieties:

$$C_t = \left\{ \frac{1}{n} \sum_{i=1}^n C_{i,t}^{\frac{\theta-1}{\theta}} \right\}^{\frac{\theta}{\theta-1}}. \quad (3)$$

The corresponding utility-based price index is given by:

$$P_t = \left\{ \frac{1}{n} \sum_{i=1}^n P_{i,t}^{1-\theta} \right\}^{\frac{1}{1-\theta}}.$$

For $b \rightarrow 1$ the *current* utility function which I denote by u_t reduces to

$$u_t = C_t^a \left(\frac{M_t}{P_t} \right)^{1-a} - \frac{\phi}{2} N_t^2.$$

The budget restriction of the representative household is given by:

$$C_t + m_{t+1} - \frac{m_t}{\pi_t} + b_{t+1} - \frac{b_t}{\pi_t} = \frac{W_t}{P_t} N_t + \Pi_t + (1 + i_t) \frac{b_t}{\pi_t} + \frac{T_t}{P_t},$$

where W_t , Π_t , T_t , $b_t = \frac{B_t}{P_{t-1}}$ and $m_t = \frac{M_t}{P_{t-1}}$ denote the nominal wage, real profits, nominal net transfers from the government, the real value of nominal bonds and real balances respectively. i_t is the one-period risk free nominal interest rate.

4.1.3 First Order Conditions

The first order conditions of the representative household evaluated at the symmetric equilibrium read:

$$aC_t^{-b} \left(aC_t^{1-b} + (1-a) \left(\frac{m_t}{\pi_t} \right)^{1-b} \right)^{\frac{b}{1-b}} = \Lambda_t, \quad (4)$$

$$\phi N_t = \Lambda_t \frac{W_t}{P_t}, \quad (5)$$

$$\frac{1}{1+i_t} = \beta E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \frac{1}{\pi_{t+1}} \right\}, \quad (6)$$

$$\Lambda_t = \beta E_t \left\{ (1-a) \frac{m_{t+1}^{-b}}{\pi_{t+1}^{1-b}} \left(aC_{t+1}^{1-b} + (1-a) \left(\frac{m_{t+1}}{\pi_{t+1}} \right)^{1-b} \right)^{\frac{b}{1-b}} + \frac{\Lambda_{t+1}}{\pi_{t+1}} \right\}, \quad (7)$$

$$C_t + m_{t+1} - \frac{m_t}{\pi_t} + b_{t+1} - \frac{b_t}{\pi_t} = \frac{W_t}{P_t} N_t + \Pi_t + (1 + i_t) \frac{b_t}{\pi_t} + \frac{T_t}{P_t}. \quad (8)$$

(6) is the bond euler equation and (7) is the euler equation with respect to money balances.

4.1.4 Government

The central bank finances its lump-sum transfers to the public by changes in the nominal quantity of money:

$$M_{t+1} - M_t = T_t.$$

It is further assumed that in each period transfers constitute a fraction of current money supply:

$$T_t = (\tau_t - 1)M_t,$$

where the percentage deviation of τ_t from its steady state $\hat{\tau}_t$ follows a first order autoregressive process

$$\hat{\tau}_t = \rho_\tau \hat{\tau}_{t-1} + u_t, \quad \rho_\tau \in [0, 1).$$

u_t is assumed to be a *White Noise Process* with variance σ_u^2 .

4.1.5 Equilibrium

In equilibrium, real wages and profits are given by

$$\frac{W_t}{P_t} = \frac{Z_t}{mu} \quad \text{and} \quad \Pi_t = \left(\frac{mu - 1}{mu} \right) Z_t N_t$$

respectively. These two results, together with the households first order conditions, (4) through (8) describe the evolution of the economy.

4.2 Understanding Key Features of the Model

Figure 1 depicts the impulse responses to a monetary shock without serial correlation, occurring in the third period. The reactions of output, employment,

consumption, real balances and the discount factor can be characterized as purely temporary one-time negative deviations from the steady state. Hence, the the positive monetary transfer is contractionary. The only variable deviating for more than one period from its long run level is the rate of inflation. Its value is above average for two quarters. To understand why there is no persistence in the reactions to monetary expansions, it is instructive to restate the household's optimality conditions under the assumption that $b = 1$:¹⁵

$$N_t = aC_t^{a-1} \left(\frac{m_t}{\pi_t} \right)^{1-a} \frac{W_t}{P_t} \quad \Rightarrow \quad C_t^{2-a} = a \left(\frac{m_t}{\pi_t} \right)^{1-a} \frac{W_t}{P_t}$$

$$m_{t+1} = \beta \frac{1-a}{a} E_t \left\{ C_{t+1} \frac{C_{t+1}^{a-1} \left(\frac{m_{t+1}}{\pi_{t+1}} \right)^{1-a}}{C_t^{a-1} \left(\frac{m_t}{\pi_t} \right)^{1-a}} \right\} + \beta E_t \left\{ \frac{C_{t+1}^{a-1} \left(\frac{m_{t+1}}{\pi_{t+1}} \right)^{1-a}}{C_t^{a-1} \left(\frac{m_t}{\pi_t} \right)^{1-a}} \frac{1}{\pi_{t+1}} \right\}. \quad (9)$$

The second equation in (9) is a conventional forward looking condition for optimal money demand. The first term on the rhs stems from the increase in next-period utility induced by a marginal increase in money holdings. Loosely speaking, for a given stochastic discount factor an increase in expected future consumption increases the expected marginal utility of real balances m_{t+1} and thus rises the demand for that asset.¹⁶ The second term embodies the link between the demand for money and its *real* interest rate $\frac{1}{\pi_{t+1}}$. An increase

¹⁵In that case the first term in the utility function becomes a Cobb-Douglas aggregator assembling consumption and real balances:

$$u_t = C_t^a \left(\frac{m_t}{\pi_t} \right)^{1-a} - \frac{d}{2} N_t^2.$$

¹⁶The positive link between expected or planned future consumption and the future marginal utility of money can be interpreted as follows: To achieve a higher level of consumption, agents need to make more transactions in the goods market which, in turn, requires larger *real* holdings of the medium of exchange - cash.

in expected inflation lowers the expected real rate of return on real balances, making it a less attractive asset. On the other hand current and future consumption can affect money demand *via* the discount factor. According to that link, m_{t+1} depends negatively on C_{t+1} and positively on C_t : since agents want to smooth consumption over time, they will try to avoid large deviations of the ratio $\frac{C_{t+1}}{C_t}$ from one by investing or desinvesting in real balances. Too low a ratio of future to current consumption $\frac{C_{t+1}}{C_t}$ will force households to raise their real cash holdings in order to be able to increase C_{t+1} and thus, to shift that ratio closer to unity.

To gain more intuition about the sign and shape of the impulse responses, let us take a more detailed look at the underlying economic mechanisms. The monetary expansion is seen by households as a positive income shock generating *for given prices* the usual income effect: agents try to raise each period's consumption demand by the same amount and lower each period's labor supply also by the same amount. To achieve that, each household tries to invest *the same* portion of his additional income in risk free bonds. But since the aggregate supply of bonds remains unchanged and equal to zero, the desire to increase bond holdings causes the nominal interest rate to fall just enough to force households to change the composition of their portfolios by leaving bond holdings unchanged and rising the desired amount of the other asset available—real balances. Since the marginal utility of consumption depends positively on real balances, the desired path of consumption expenditure gets altered with future consumption and labor supply being increased relative to their respective current values.¹⁷ At the same time, as the current Z_t is given, the planned increase in current consumption demand accompanied by a lowering of current labor supply leads to an increase in current and expected nominal wages which, under constant markups, is completely passed through to

¹⁷See the first line in (9).

nominal prices, leading to an increase in *current* inflation π_t . Expected future nominal wages and prices will also tend to rise since planned next-period consumption expenditure (labor supply) also get larger (smaller). But since the reactions of that two variables are affected by the increase in money holdings in the way just described, the steady state deviation of expected future inflation might turn to be stronger or weaker than that of present inflation, or even be negative, depending on whether desired next-period consumption or labor supply responds more strongly to changes in real money holdings. Note that real balances has two opposing effects on labor supply: An increase in m_t has a positive direct effect on N_t (see the first equation in the first line of (9)). At the same time, everything else given, the increase in labor supply increases labor income and makes a higher level of consumption possible. On the aggregate level consumption depends on m_t according to the second equation in the first line of (9). But a higher level of consumption implies a lower marginal utility of that variable and thus, creates an incentive for households to decrease labor supply. It turns out that the overall effect of changes in $\frac{m_t}{\pi_t}$ on N_t is positive and can be described by the following equation:

$$N_t = a^{\frac{1}{2-a}} \left(\frac{m_t}{\pi_t} \right)^{\frac{1-a}{2-a}} \left(\frac{W_t}{P_t} \right)^{\frac{1}{2-a}}.$$

The increase in current inflation and the reaction of future inflation should be such that in each period the disparity between aggregate consumption and labor supply and thus production, is eliminated. Depending on how the inflation path adjusts, both equilibrium consumption and labor in the present as well as in the future can fall, increase or remain unchanged.¹⁸ If $E_t \pi_{t+1}$ actually changes, the incentive to build up money balances gets altered, starting a new loop of adjustments in desired current and future consumption demand, labor supply and inflation, until the new intertemporal equilibrium is reached.

¹⁸Note that only changes in expected future inflation affect the real interest rate of money balances.

Now observe that consumption depends on current inflation through the ratio $\frac{m_t}{\pi_t}$ and thus money demand m_{t+1} is affected by π_t only *via* terms of the form $\frac{m_{t+1}\pi_t}{m_t\pi_{t+1}}$. Log-linearizing one of that terms and taking expectations as of time t yields:

$$\hat{\tau}_t - E_t \hat{\pi}_{t+1}$$

which does not depend on current inflation π_t . Further, the fact that C_{t+1} and π_{t+1} appear in the second equation in (9) just induces an additional, *indirect*, log-linear link between \hat{m}_{t+1} and $E_t \hat{\pi}_{t+1}$. To see that, eliminate consumption from the system (9) and log-linearize around the nonstochastic steady state under the assumption $\hat{Z}_t = 0 \forall t$. The resulting equation reads:

$$\hat{m}_{t+1} = - \left(\frac{2\pi^*(1-a) + \beta}{\pi^* - \beta} \right) E_t \hat{\pi}_{t+1} + \frac{(1-a)\pi^*}{\pi^* - \beta} \hat{\tau}_t. \quad (10)$$

The link between current money demand and expected inflation is the result of the overlapping effects on m_{t+1} arising through the interdependence between m_{t+1} and $E_t \pi_{t+1}$ and current and next period consumption as well as real balances mentioned above. (10) is a reduced form, forward looking money demand equation. Money supply evolves according to

$$\hat{m}_{t+1} = \hat{m}_t - \hat{\pi}_t + \hat{\tau}_t. \quad (11)$$

(10) and (11) constitute a dynamic *supply-demand* system with an expected time path of prices given by $\hat{\pi}_t, E_t \hat{\pi}_{t+1}, E_t \hat{\pi}_{t+2}, \dots$. In equilibrium the price expectations of money suppliers should be equal to that of the agents demanding money. So, one can shift (11) one period forward in time, take conditional expectations as of time t , take into account that $\hat{\tau}_t$ is a White Noise process and then eliminate expected inflation from (10). The resulting relationship

$$\hat{m}_{t+1} = \underbrace{\frac{2\pi^*(1-a) + \beta}{2\pi^*(1-a) + \pi^*}}_{\in(0,1)} E_t \hat{m}_{t+2} + \frac{(1-a)\pi^*}{2\pi^*(1-a) + \pi^*} \hat{\tau}_t$$

is a stochastic forward looking difference equation which should be solved forward as its root lies outside the unit circle. The solution is very simple and is computed by each agent in forming her rational expectations about inflation and other variables:

$$\hat{m}_{t+1} = \frac{(1-a)\pi^*}{2\pi^*(1-a) + \pi^*} \hat{\tau}_t.$$

Hence, the relative deviation of money balances from its steady state level follows a White Noise process. Now it is straightforward to show that

$$E_t \hat{m}_{t+2} = E_t \hat{\tau}_{t+1} = 0 = E_t \hat{m}_{t+3} = E_t \hat{m}_{t+4} = \dots$$

and therefore

$$E_t \hat{\pi}_{t+1} = \hat{m}_{t+1}, \quad E_t \hat{\pi}_{t+2} = 0, \quad E_t \hat{\pi}_{t+3} = 0, \dots$$

But if agents expect next-period inflation to rise by the same amount as their real balances, their expected wealth in $t + 1$ will remain unchanged implying that they will have no incentive to change next-period consumption which, in turn, leaves the marginal utility of consumption and thus labor supply in $t + 1$ unchanged.¹⁹ Since the expected steady state deviations of real balances and inflation in all future periods are equal to zero, nobody will expect any positive or negative wealth effects of real money holdings in that periods.

What happens in the period in which the shock occurs? For a given level of consumption the large increase in inflation induces a sharp decline in the current marginal utility of consumption. As a result, labor supply falls even more and leads to a further decline in labor as well as dividend income. Since at the same time the positive income effect of the monetary shock is almost offset by the rise of the inflation rate, households have to reduce current consumption. Since the time path of the marginal utility of consumption is altered agents face an additional, utility based incentive to lower current consumption

¹⁹See the first equation in (9).

relative to its future level. However, the reduction of C_t is not sufficient to compensate (offset) the negative effect of inflation on the marginal utility of consumption. Therefore labor supply and thus, output unambiguously fall. One can see the overall effect of inflation on consumption formally by inspecting the second equation in the first line of (9): Since m_t is given, the increase in π_t lowers consumption demand. Observe that π_t affects C_t through three different channels. The direct one is negative *via* the dampening of the income effect of the monetary transfer. The second one is positive: the lower C_t caused by a higher π_t increases the marginal utility of consumption and the incentive to work. That, in turn, leads to a higher labor income and thus increases consumption demand. The third one is again negative and results from the direct negative dependence of the marginal utility of consumption on the rate of inflation.

If utility were additively separable in money and consumption the increase in real balances or *current* inflation won't alter the marginal utility of consumption or that of labor. Therefore current and future nominal wages will jump by the same amount with the consequence that in the entire future inflation remains at its steady state level while current inflation rises by an amount just sufficient to offset the positive income effect of the monetary transfer. As a result, nothing except current inflation would change in that economy. With utility non-additively separable in consumption and real balances the pattern of both, desired consumption and labor supply, are altered by changes in real balances m_{t+1}, m_{t+2}, \dots and current and expected inflation $\pi_t, E_t\pi_{t+1}, E_t\pi_{t+2}, \dots$

Higher values of b as well as lower values of a imply that changes in real balances or inflation have a stronger impact on the marginal utility of consumption. For that reason changing the two parameters in that way magnifies the impulse responses to an one time monetary expansion without changing

the qualitative predictions of the model.

The implication that positive monetary disturbances are contractionary is at odds with the conventional thinking as well as the empirical evidence²⁰ about the effects of monetary policy. To make the theory more realistic in the next section I extend it by the the assumption of market share competition in the goods market *à la* Phelps and Winter (1970).

5 A Model with Fixed Capital and Market Share Competition

I refer to this model as the *Customer Markets Model* with fixed capital.

5.1 The Theoretical Framework

Let us assume that the consumption index is given by

$$C_t = \left\{ \frac{1}{n} \sum_{i=1}^n x_{i,t}^{\frac{1}{\theta}} C_{i,t}^{\frac{\theta-1}{\theta}} \right\}^{\frac{\theta}{\theta-1}}, \quad (12)$$

where $x_{i,t}$ evolves according to

$$x_{i,t+1} = g \left(\frac{P_{i,t}}{P_t} \right) \cdot x_{i,t} \quad (13)$$

The corresponding demand function faced by an arbitrary firm i is given by:

$$C_{i,t} = x_{i,t} \cdot \left(\frac{P_{i,t}}{P_t} \right)^{-\theta} \cdot \frac{C_t}{n}. \quad (14)$$

This is basically the assumption underlying the "*Customer Markets Model*" developed by Phelps and Winter (1970). They interpret $x_{i,t}$ as the market share of firm i . But that variable can be also interpreted as an indicator of customers' satisfaction with the pricing behavior of firm i , or as an indicator

²⁰See Christiano *et al.* (2005).

for the subjective weight assigned to good i within the consumption bundle. In the current paper $x_{i,t}$ is called market share. I assume that the function $g(\cdot)$ governing its law of motion has the properties:

$$g(1) = 1, \quad g' \left(\frac{P_{i,t}}{P_t} \right) < 0,$$

and assume the following functional form for it

$$g \left(\frac{P_{i,t}}{P_t} \right) = \exp \left(\gamma \left(1 - \frac{P_{i,t}}{P_t} \right) \right),$$

where $\gamma > 0$ is to be calibrated *via* the steady state of the economy. Because $x_{i,t}$ depends on the past pricing behavior of the firm, its profit maximization problem becomes dynamic: In this economy each firm faces a trade off between maximizing its current profits and maximizing its future market share.

The first order condition of an arbitrary firm with respect to its relative price reads:

$$\left(\frac{P_{i,t}}{P_t} \right)^{-\theta} x_{i,t} D_t - \theta \left(\frac{P_{i,t}}{P_t} - \mu_t \right) \left(\frac{P_{i,t}}{P_t} \right)^{-\theta-1} x_{i,t} D_t + \frac{g_1 \left(\frac{P_{i,t}}{P_t} \right)}{g \left(\frac{P_{i,t}}{P_t} \right)} \Omega_t = 0,$$

where μ_t denotes marginal costs and

$$\begin{aligned} \Omega_t &= E_t \left\{ \sum_{j=1}^{\infty} \beta^j \frac{\Lambda_{t+j}}{\Lambda_t} x_{i,t+j} \left(\frac{P_{i,t+j}}{P_{t+j}} - \mu_{t+j} \right) \left(\frac{P_{i,t+j}}{P_{t+j}} \right)^{-\theta} D_{t+j} \right\} = \\ &= E_t \left\{ \beta \frac{\Lambda_{t+1}}{\Lambda_t} x_{i,t+1} \left(\frac{P_{i,t+1}}{P_{t+1}} - \mu_{t+1} \right) \left(\frac{P_{i,t+1}}{P_{t+1}} \right)^{-\theta} D_{t+1} \right\} + E_t \left\{ \beta \frac{\Lambda_{t+1}}{\Lambda_t} \Omega_{t+1} \right\} \end{aligned} \quad (15)$$

is the expected present value of future profits. Defining the markup over marginal costs as

$$mu_{i,t} = \frac{P_{i,t}}{P_t \mu_t}, \quad mu_t = \frac{1}{\mu_t},$$

one can write the FOC, evaluated at the symmetric equilibrium, as

$$mu_t = \frac{-\theta}{1 - \theta - \gamma \frac{\Omega_t}{C_t}} \quad (16)$$

In a symmetric intertemporal equilibrium in each period each firm sets the same price as all other firms. The most important implication regarding market shares is that $x_{i,t}$ equals one for all t and all i . According to equation (16) the equilibrium markup depends positively on current demand and negatively on the present value of future profits. In the static monopolistic competition model markups are given by

$$mu_t = \frac{\theta}{\theta - 1} \quad (17)$$

implying that at any point in time and in any given state of the economy pass-through of marginal cost changes to prices is complete. Unlike that model, in an environment characterized by market share competition markups will be generally time varying. Whether pass-through of marginal costs to prices will turn to be greater, lower or equal to one depends on the relative strength of the reactions of C_t and Ω_t to exogenous shocks. In the present model the discount factor is endogenous and strongly linked to current and next-period consumption, real balances and inflation - as shown above for $b = 1$ the discount factor is given by:

$$DF_t = \beta E_t \left\{ \frac{C_{t+1}^{a-1} \left(\frac{m_{t+1}}{\pi_{t+1}} \right)^{1-a}}{C_t^{a-1} \left(\frac{m_t}{\pi_t} \right)^{1-a}} \right\}.$$

For example, consider a positive monetary shock which *at given prices* increases current consumption *via* the positive income effect but also puts an upward pressure on current inflation as explained in the previous section. Obviously, the temporary (or even an one time) increase in current consumption will have a positive *direct* effect on markups but if at the same time the increase

in current inflation π_t and/or next period cash balances m_{t+1} is *sufficiently*²¹ large relative to the increase in C_t then the increase in the discount factor will be larger than that of current consumption, probably causing the term $\frac{\Omega_t}{C_t}$ to rise and thus markups to fall.

The equilibrium in this economy is described by the household's optimality conditions (4) through (8), the laws of motion of markups and the present value of future profits (16) and (15) respectively, and the equation specifying monetary policy.

5.2 Understanding Key Features of the Model

Figures (2) and (3) in Appendix B depict the impulse responses to a one time monetary expansion for $\theta = 0.6$ and $\theta = 1.4$ respectively. In this economy inflation increases by 0.8322 (for $\theta = 0.6$) percent and 0.8382 percent (for $\theta = 1.4$) on impact, compared to 0.8433 percent in the model presented in the previous section. Hence the inclusion of market share competition strengthens the non-neutrality of money. Unfortunately, the change is quantitatively very small.

What's the intuition behind these results? Since households expect next period inflation to exactly offset any positive wealth effects stemming from the increase in real balances m_{t+1} and at the same time all future inflation rates, markups and productivity levels to remain constant they will have no incentive to set consumption, labor supply and savings at values different from their respective steady state values. As a consequence, the expected discounted present value of firm's profits Ω_t changes only because the discount factor DF_t changes, while the latter deviates from its steady state level only because the product $C_t^{1-a}\pi_t^{1-a}$ does. Hence, the log-deviation of the markup from its steady

²¹Actually one must compare the responses of C_t^a and $m_{t+1}^{1-a}\pi_{t+1}^{1-a}$.

state level can be represented as:

$$\hat{m}u_t = -\xi((1-a)\hat{C}_t + (1-a)\hat{\pi}_t - \hat{C}_t) = \xi a\hat{C}_t - \xi(1-a)\hat{\pi}_t,$$

where $\xi = \frac{\gamma \frac{\Omega^*}{C^*}}{\gamma \frac{\Omega^*}{C^*} + \theta - 1}$. With $a = 0.9$ the difference between the log-deviation of the discount factor and that of current consumption

$$\hat{D}F_t - \hat{C}_t = -a\hat{C}_t + (1-a)\hat{\pi}_t$$

will be positive as long as the increase in inflation is sufficiently large relative to the reaction of consumption. The latter is the case in all simulations performed. The optimal reaction of firms to an increase in Ω_t relative to C_t is to lower markups. As a result real wages (profits) rise (fall) forcing households to increase labor supply. But at the same time, the higher labor enables the economy to produce and therefore consume more. The potential to increase consumption as well as the above average inflation reduce the marginal utility of consumption, generating an incentive for households to reduce labor supply. Whether working hours will rise or fall depends on the relative strength of the positive effect of the markup and the negative effect of the fall in the marginal utility of consumption. Which of this two effects dominates depends on the short run elasticity of demand θ . Why? Optimal labor supply is given by

$$N_t = aC_t^{a-1} \left(\frac{m_t}{\pi_t} \right)^{1-a} \frac{W_t}{P_t}.$$

Its relative deviation from the steady state can be written as

$$\hat{N}_t = -\hat{C}_t + (\xi - 1) \underbrace{((1-a)\hat{\pi}_t - a\hat{C}_t)}_{:= -\hat{m}u_t},$$

and by imposing the equilibrium condition $N_t = C_t$ we get:

$$\hat{N}_t = \frac{(\xi - 1)(1 - a)}{2 + a(\xi - 1)} \hat{\pi}_t. \quad (18)$$

Since for $\theta \in (0, 1)$ $\xi > 1$, while $\theta \geq 1$ implies $\xi \in (0, 1]$, working hours respond positively (for $\theta < 1$) and negatively (for $\theta > 1$) to fluctuations of the

inflation rate. In the case of $\theta \in (0, 1)$ and thus $\xi > 1$ the slope of the first derivative of the current profit function is *relatively* small in absolute value. As a result, when changes of current inflation and/or current consumption occur firms need a *relatively* large adjustment of the markup in order to ensure that their respective Euler equations are still satisfied. Put differently, if current demand is relatively inelastic (the case of a low θ) the economy needs a larger adjustment of the markup to restore equilibrium after a monetary shock. In that case, for a given level of consumption, the fall of the markup is stronger than the decrease of the marginal utility of consumption, both caused by the increase in inflation. As a consequence, working hours increase. The resulting higher labor income for any given real wage as well as higher profits for any given markup level enable households to increase consumption. The latter, in turn, dampens the reactions of the markup and the marginal utility of consumption slightly. For a given level of C_t $\theta > 1$ and thus $\xi \in (0, 1)$ implies that the fall in the marginal utility of consumption is stronger than the increase in the real wage, both caused by the jump of the inflation rate. Therefore, in that case hours fall shifting income and consumption down. The reaction of consumption, again, implies a slight weakening of the effects induced by the rise in π_t .

Another way to gain intuition about the key mechanism in this model is as follows: Suppose, initially firms miss the occurrence of the monetary shock and do not adjust the markup. Then consumption and inflation will react in exactly the same way as in the previous section - there will be a drop in current consumption and a large jump in current inflation. But can this situation be an equilibrium? The negative (positive) reaction of consumption (inflation) will induce an unambiguous²² increase in

$$\hat{\Omega}_t - \hat{C}_t = D\hat{F}_t - \hat{C}_t = -a\hat{C}_t + (1 - a)\hat{\pi}_t.$$

²² $\frac{m_{t+1}}{\pi_{t+1}}$ as well as all other future variables are expected to remain unchanged.

Hence, each firm will find it optimal to lower its markup. As a result the real wage will rise generating an incentive for households to increase labor supply. Thus, in this model for any level of consumption, labor supply will be higher than in the one developed in the previous section. For $\theta < 1$ labor, output and consumption actually increase, otherwise they fall.

According to figures (2) and (3) the major shortcoming of the model is that the one-time monetary disturbance induces purely temporary, one-time reactions of the main economic aggregates. This absence of any persistence is at odds with the empirical evidence provided by a vast number of studies employing structural VARs.²³ In the following sections I introduce different forms of capital accumulation and show that aside from making the production side of the economy more realistic, the inclusion of capital as a second state variable also substantially increases the persistence as well as the magnitude of the responses to monetary shocks.

6 Capital Accumulation and Static Monopolistic Competition

6.1 The Theoretical Framework

Let us extend the model presented in section 4 by assuming that there is a second factor of production called capital. It is completely owned by households and in each period it is supplied to the firms at the rental rate R_t . The production function of an arbitrary firm i is of the Cobb-Douglas type and exhibits constant returns to scale:

$$Y_{i,t} = C_{i,t} + I_{i,t} = Z_t N_{i,t}^\omega K_{i,t}^{1-\omega}, \quad \omega \in (0, 1),$$

²³See for example Christiano *et al.* (1999, 2005).

where Y_i is the sum of the production of the i -th type of consumption good C_i and the i -th type of investment good over which firm i has monopoly power. Capital is accumulated according to the law of motion

$$K_{t+1} = I_t + (1 - v)K_t, \quad (19)$$

where K_t and $I_t = \left(\frac{1}{n} \sum_{i=1}^n I_{i,t}^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}}$ denote the aggregate stock of capital and aggregate investment respectively. $v \in (0, 1)$ is the depreciation rate. Assuming that investment and consumption are perfect substitutes the budget restriction of the representative household reads:

$$C_t + I_t + m_{t+1} - \frac{m_t}{\pi_t} + b_{t+1} - \frac{b_t}{\pi_t} = \frac{W_t}{P_t} N_t + R_t K_t + \Pi_t + (1 + i_t) \frac{b_t}{\pi_t} + \frac{T_t}{P_t}. \quad (20)$$

The Euler equation with respect to the stock of capital takes the form

$$\Lambda_t = \beta E_t \{ \Lambda_{t+1} (1 + R_{t+1} - v) \}, \quad (21)$$

where Λ_t is the Lagrangean multiplier corresponding to the household's budget constraint.

In an environment characterized by monopolistic competition the equilibrium real rental rate of capital is smaller than the marginal product of capital and is given by

$$R_t = \frac{1 - \omega}{mu_t} \left(\frac{N_t}{K_t} \right)^\omega.$$

Since in this version of the model there is only static monopolistic competition in the goods market the markup will be constant and tightly related to the short run elasticity of demand θ according to :

$$mu_t = mu = \frac{\theta}{\theta - 1}, \quad \forall t.$$

A description of the equilibrium in this economy is easily obtained - just add (19) and (21) to the equilibrium conditions of the model presented in section 4 and replace (8) by (20).

6.2 Understanding Key Features of the Model

Figure 4 in Appendix C depicts the impulse responses to a non-autocorrelated monetary shock. The initial sharp decline in working hours, output and consumption is due to the same mechanisms as that described in section 4: despite the positive income effect on consumption induced by the monetary transfer the jump of the inflation rate is sufficiently large to lower the marginal utility of current consumption. As a result the incentive to work "*today*" decreases relative to the incentive to supply labor in future periods, when the marginal utility of consumption is relatively high, because of the lower inflation and higher real balances. A similar reasoning governs the reaction of investment - it is optimal for households to accelerate capital accumulation at the expense of a lower consumption level "*today*" in order to be able to consume more "*tomorrow*", when the marginal utility of consumption is relatively high. As can be seen, the increase in inflation alters the time path of the marginal utility of consumption sufficiently strongly, leading to a healthy increase in investment despite the fall in current labor and output. The additionally accumulated capital enables the economy to produce and consume more in the periods after the shock. The small positive deviation of the real wage from its steady state value in the period of the shock is due to the diminishing marginal productivity of labor. The above average wages in the aftermath of the shock are due to the increased stock of capital. Working hours are also above their long run level because of the increased marginal productivity of labor. In the period after the shock there is a large jump in output caused by the higher capital stock on the one hand and the above average hours on the other. The persistence in the impulse responses also results from the increase of the capital stock which is only slowly reduced to its initial level.

According to the shape of the reactions of the main economic aggregates displayed in figure 4 monetary expansions are expansionary with an one-period

delay - initially they induce a contraction but a long-lasting expansion in the aftermath of the shock. The impulse responses of some important macroeconomic variables to a positive monetary shock estimated by Christiano *et al.* (2005) also exhibit a delay of one or two periods. Nevertheless, there are several dimensions along which the predictions of the model presented in this section are at odds with the evidence provided by Christiano *et al.* (2005). For example, although output, consumption and working hours do not reach their respective highest levels initially (in the period of the shock), their impulse responses to the monetary disturbance are not *U-shaped* and of very limited magnitude. The only reaction which can be characterized as substantial is that of investment expenditure. The latter increases on impact only to fall below its long run level in the period after the shock. Christiano *et al.* (2005) find a similar, but more *U-shaped* response of investment in the data. Unfortunately, the deviation of investment from its steady state level is much stronger than what is observed empirically.

The magnitude as well as the persistence of the impulse responses predicted by the model are virtually insensitive to variations in the inverse of the elasticity of substitution between consumption and real balances b .

In the next section I explore how the introduction of market share competition affects the predictions of the MIU-model with endogenous capital presented in this section.

7 Capital Accumulation and Market Share Competition

I refer to the model presented in this section as the *Customer Markets Model* with fully flexible capital. The version developed in subsection 7.3 is called the *Customer markets Model* with adjustment costs of capital.

7.1 The Theoretical Framework

The introduction of market share competition just adds two further equilibrium conditions to the system describing the evolution of the economy presented in the previous section. Both of them result from the dynamic considerations arising within the firms' optimization problem in an environment characterized by market share competition. The two new equations are the laws of motion for markups and the present value of future profits (16) and (15) respectively. All other equilibrium conditions remain the same as in section 6.

7.2 Understanding Key Features of the Model

Figures 5 through 8 provided in Appendix C display the impulse responses to a one-time monetary expansion predicted by the model for different values of the short run elasticity of demand θ .

How does the inclusion of market share competition alter the qualitative predictions of the model with endogenous capital accumulation? Since markups become endogenous, the reactions of real wages and profits will turn to be different than the ones shown in figure 4. For example, if firms reduce markups as a reaction to the monetary disturbance then for any given deviation of labor and output from their respective steady state levels the impact response of real wages (profits) will be stronger (weaker) than it was the case in the model presented in section 6. Hence, the income and substitution effects induced will force households to work more and therefore enable the economy to produce more than the one in the previous section. As figures 5 through 8 show, for a broad range of values of θ the impact reaction of the expected present value of future profits Ω_t is stronger than that of current demand $Y_t = C_t + I_t$ with the consequence that firms find it optimal to lower markups. In the *Customer Markets Model* without capital the sole reason for the increase in Ω_t was the sharp jump in the discount factor caused by the increase

in inflation while future profits remained unchanged. Unlike that model, in the economy presented in this section there is also a second force, beyond the increase of the discount factor, leading to an increase in the expected present value of profits: in the period of the shock households accumulate additional capital which increases their future income²⁴ with the consequence of a higher aggregate demand for goods in the aftermath of the shock. Everything else given, a higher level of future demand increases the expected present value of firms' profits. The decrease in the current markup level has a positive effect on the real wage and so, generates an incentive to supply more labor than in the economy without market share competition.²⁵ Figures 5 through 8 reveal that if the short run elasticity of demand is not too large²⁶ the drop in markups is sufficiently large to induce a large enough increase in the real wage which, in turn, more than compensates the negative effect on the labor supply decision induced by the large decline in the current marginal utility of consumption. Because of the large increase of investment in the period of the shock the economy accumulates substantial additional capital which leads to an even sharper increase in output in the period after the shock. Since inflation returns to its long run level in the period after the shock, the deviation of the discount factor from its steady state value becomes very small, implying a smaller deviation from the long run level of Ω_t in that period. As can be seen, if θ lies in

²⁴For a given amount of hours worked and a given markup the additionally accumulated capital increases labor income by making working hours more productive, increases capital income despite the induced fall in the real interest rate (*diminishing marginal productivity of capital*) and it also has a positive effect on future profits. Note that the sum of the three income types does not depend on the markup mu_t . Hence, from the point of view of the individual household markup variations do only change the composition of the income stream but not its level.

²⁵See section 6.

²⁶Values of θ smaller than 1.1 imply a positive impact response of hours to monetary shocks.

the empirically relevant range, the effect of capital accumulation is sufficiently strong to push output to a value higher than that of Ω_t in the aftermath of the shock. As a consequence, the markup rises to an above average level more or less sharply reducing (*via* the downward pressure on wages) the incentive to work. According to the impulse responses shown, lower values of θ imply stronger reactions of markups which, in turn, induce a larger increase in working hours in the period of the shock and than a larger drop of that variable thereafter (compare figure 5 with figure 6).

Values of θ near one imply delayed responses of output and employment to monetary innovations with both variables reaching their highest values in the period after the shock. While such a prediction should be seen as more or less in line with the existing VAR evidence, the responses of several other variables to monetary disturbances are not consistent with the patterns found in the data. For example, in the model economy developed in this section a money supply loosening induces a large short-run contraction of consumption. In the periods after the shock consumption expenditure reaches an above average value but its deviation from the steady state level is very small. The responses of investment and real wages also do not exhibit an *U-shaped* form. Both variables reach their highest deviation from the stationary equilibrium in the period in which the monetary innovation occurs. Furthermore, the reaction of investment is many times larger than measured by any of the existing empirical studies. In addition, investment is the only variable the response of which can be characterized as a *substantial real effect* of monetary policy. The reactions of the remaining real variables are persistent but of limited magnitude. For example, in the case $\theta = 0.5$ the largest deviation of output from its steady state, reached in the second period, is equal to 0.014%, which is much less than what is empirically observed²⁷ - about 0.4%.

²⁷See Christiano *et al.* (2005)

Similar to the economy of section 6 the magnitude as well as the persistence of the impulse responses in the current model are virtually insensitive to variations in the elasticity of substitution between consumption and real balances $1/b$.

7.3 A Customer Markets Model with Adjustment Costs of Capital

How does the inclusion of adjustment costs of capital alter the dynamic properties of the model? The economic intuition suggests that if investment is sufficiently costly households will be reluctant to accelerate capital accumulation in such a dramatic manner as they do in the models developed in sections 6 and 7. As a consequence, there will be more resources left for consumption in the period of the shock, enabling the theory to get rid of the counterfactual sharp increase (decline) in investment (consumption). In addition, the presence of adjustment costs of capital will strengthen the incentive to raise future real money holdings m_{t+1} which, in turn, will induce a positive wealth effect in $t + 1$, $t + 2$, ... and so, probably, at least partly, preserve the persistence in the impulse responses. Note that the wealth effect in $t + 1$ induced by a higher level of real balances triggers off qualitatively the same reactions as the positive income effect of the monetary disturbance in the period of the shock. Furthermore, because the introduction of capital adjustment costs shifts the properties of the model towards the fixed capital case, one could expect to be able to make the real effects of monetary shocks arbitrarily large by setting the short run elasticity of demand θ at a sufficiently low value and the elasticity of substitution between consumption and real balances b at a sufficiently high value. In other words, since the *Customer Markets Model* with adjustment costs of capital represents the intermediate case between the model developed in section 5 and the one presented in section 7 there is no *a priori* reason not

to expect that it will be a combination of the favorable properties of the latter two models.

Formal Details: The flexibility of investment is reduced in an *ad hoc* manner by assuming that there is an additional adjustment cost of capital represented by the strict concavity of the strictly increasing function $\phi\left(\frac{I_t}{K_t}\right)$ in

$$K_{t+1} = \phi\left(\frac{I_t}{K_t}\right) K_t + (1 - v)K_t. \quad (22)$$

Further, $\phi(\cdot)$ has the properties:

$$\phi\left(\frac{I}{K}\right) = \phi(v) = v, \quad \phi'(v) = 1,$$

where I and K are the steady state levels of investment and capital respectively.²⁸ The first assumption ensures that the steady state is characterized by the absence of adjustment costs while the second implies that in the stationary equilibrium *Tobin's q* is equal to one. Formally the equilibrium conditions (4) through (8) ought to be adjusted by including the household's first order condition with respect to investment

$$q_t = \frac{\Lambda_t}{\phi'\left(\frac{I_t}{K_t}\right)},$$

substituting the conventional transition equation for capital by (22) and replacing the first order condition with respect to next period's stock of capital (21) by

$$q_t = E_t \left\{ \Lambda_{t+1} \frac{1 - \omega}{mu_{t+1}} \frac{Y_{t+1}}{K_{t+1}} + q_{t+1} \left(1 - v + \phi\left(\frac{I_{t+1}}{K_{t+1}}\right) - \phi'\left(\frac{I_{t+1}}{K_{t+1}}\right) \frac{I_{t+1}}{K_{t+1}} \right) \right\},$$

where q_t denotes the Lagrangean multiplier attached to (22) and q_t/Λ_t equals *Tobin's q*.

The individual firm faces the same optimization problem and thus, behaves according to the same optimality conditions as in the economy with market

²⁸The assumed low of motion of capital is due to Jerman (1998).

share competition and fully flexible capital described in the first part of section 7.

Impulse Responses to Monetary Shocks

In this model there is a further unobservable parameter besides a and b to be chosen - the elasticity of the adjustment cost function $\phi\left(\frac{I_t}{K_t}\right)$ with respect to the investment capital ratio I_t/K_t . Let ζ denote that elasticity. I first set ζ at the value which, combined with $\theta = 0.6$, implies that the theoretical model reproduces the empirically observable relation between the standard deviation of investment and that of output.²⁹ The parameters of the utility function a and b were again set at 0.9 and 1 respectively. First, I explore how the short run elasticity of demand θ affects the qualitative and quantitative predictions of the model. Figures 9 through 11 depict the impulse responses to a one-time monetary shock in $t = 3$, and reveal a rather disappointing picture. As expected, by making investment more costly agents become unwilling to increase that variable by an amount as large as in the case of a fully flexible capital. However, at the same time the qualitative as well as quantitative properties of the model with respect to all other variables except consumption are dramatically shifted towards that of the *Customer Markets Model* without capital. Much as in that model, output, wages, hours and markups reach their largest deviations from the stationary equilibrium in the period of the shock. The lower the value of θ the more pronounced the fall in markups and thus, the stronger the increase in wages. As a result, for relatively low (large) values of θ hours and thus output increase (fall). Unfortunately consumption reacts to monetary shocks in a similar way as it does in the *Customer Markets Model* with fully flexible capital presented in the first part of the current section - it decreases more or less sharply on impact and rises to an above average level in

²⁹The total factor productivity Z_t is assumed to be autocorrelated with coefficient of autocorrelation equal to 0.9641. (See Appendix A for calibration details.)

the periods after the shock. In other words, instead of assembling the favorable properties of the economy with fixed and that with flexible capital, the model with adjustment costs rather turns to be a combination of the undesirable features of that theories. By varying the parameters of the model it is possible to get arbitrarily close to the intermediate case which is characterized by impulse responses of significant magnitude³⁰ on the one hand and a more or less delayed and persistent deviations from the steady state³¹ on the other. However, that intermediate case has an important drawback - the reactions of consumption to monetary shocks is negligible. The latter is at odds with the bulk of the empirical evidence.

How does the degree of inflexibility of capital accumulation affect the results? As figure 14 shows, setting ζ to the value estimated by Jerman (1998) and thus making investment much more costly just makes the current version of the *Customer Markets Model* a close replication of the one with fixed capital. Hours, production and consumption increase by more on impact, while the reaction of investment is much weaker. As shown in figure 17, making investment less expensive, $\zeta = 0.00004347$, just leads to a new *Customer Markets Model* which mimics its version with fully flexible capital.

Variations in the elasticity of substitution between real balances and consumption $1/b$ have similar effects on the model's predictions as in the fixed-capital case. The higher the value of b and thus the lower the elasticity of substitution between C_t and $\frac{M_t}{P_t}$ the larger the magnitude of the impulse responses. Figure 19 depicts the case $b = 20$. Relatively low values of b imply that $\frac{M_t}{P_t}$ and C_t are relatively close substitutes. Therefore from the household's point of view there is a higher incentive to compensate the drop in real balances induced by the increase in inflation in the period of the shock by choosing a higher level of consumption C_t . As a result, in the case of a low b the mone-

³⁰As in the model with fixed capital.

³¹As in the model with flexible capital.

tary disturbance alters the time path of the marginal utility of consumption less heavily than when b is high. Consequently, in the former case there are weaker incentives to adjust labor supply and the stock of capital. The impulse responses to a monetary shock in the case $b = 0.02$ are displayed in figure 20.

A comparison with the New Keynesian Model: For the sake of better comparability I use a version of the *New Keynesian Model* characterized by the same utility function, the same production technology and the same law of motion for capital as in the *Customer Markets Model* with adjustment costs of capital. From a technical point of view the only difference between the two models concerns the firm's condition for optimal price setting evaluated at the symmetric equilibrium. In the *New Keynesian Model* it reads:

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} - \frac{(1 - \varphi)(1 - \varphi\beta)}{\varphi} \hat{m}u_t, \quad (23)$$

where φ denotes the fraction of firms which are not allowed to adjust their prices within a period. (23) is known as the *New Keynesian Phillipps Curve* and replaces (15) and (16). To bias the results towards a better performance of the *New Keynesian Model* I assume a relative high degree of price stickiness, $\varphi = 0.75$ or $\varphi = 0.5$. Both values are (much) higher than what is consistent with the evidence provided by Bils and Klenov (2004) and Klenov and Kryvtov (2005): $\varphi \approx 0.33$. Figures 12 and 13 depict the impulse responses to a non-autocorrelated monetary shock for $\varphi = 0.75$ and $\varphi = 0.5$ respectively. θ was set equal to 6 in order to ensure that the steady state markup equals 1.2. a and b again take the values 0.9 and 1. The value of $\zeta = -0.024$ implies that for $\varphi = 0.75$ investment is about 4.65 time as volatile as output. In both cases the impact reactions to the monetary innovation are more than ten times stronger than in the *Customer Markets Model*. Further, the *New Keynesian Model* implies more persistent deviations from the steady state³² However, slightly

³²See figure 12.

reducing the degree of price rigidity from $\varphi = 0.75$ to $\varphi = 0.5$ dramatically worsens the predictions of the model with respect to the duration of the impulse responses.³³ For $\varphi = 0.33$ the performance of the model becomes even worse. In summary, the *New Keynesian Model* ascribes much more relevance to monetary shocks than the *Customer Markets Model* does. Furthermore, as figures 9 through 13 show, for intermediate values of capital adjustment costs the predictions of the former model are closer to the empirical evidence than that of the latter. Setting ζ at Jerman's value in the *New Keynesian Model* makes the impulse responses even more weaker with all macroeconomic aggregates except investment reaching their maximum in the period after the shock (figures 15 and 16). This kind of one period delay is consistent with the findings of Christiano *et al.* (1999, 2005). Setting ζ at 0.00004347 leads to a worsening of the predictions of the *New Keynesian Model* - the persistence in the impulse responses of all variables except consumption almost completely disappears (figure 18). In addition, there is the counterfactual implication of a large drop in consumption in the period of the shock. Higher values of b in the *New Keynesian Model* imply more persistent but less pronounced reactions to nominal disturbances (figures 21 through 24).

The results can be summarized as follows. If capital accumulation is relatively flexible the *Customer Markets Model* implies more realistic reactions to monetary disturbances than the model with sticky prices does. Otherwise the reverse is true.

8 Business Cycles Moments

In order to evaluate the goodness of a particular business cycle model, it has become a common practice to compare its quantitative predictions with respect

³³See figure 13.

to a set of second moments with the same set of moments found in empirical data. The same strategy is chosen in the current paper. Since the goal of such an exercise is not the examination of the qualitative properties of the model, but rather the computation of its exact quantitative predictions, it is desirable to calibrate it in as sophisticated as possible. This is done in Appendix A.

I perform two simulation experiments - one with $b = 20$ and the other with $b = 0.02$. As shown in sections 5 and 7 higher values of b magnify the impulse responses to monetary disturbances. In both simulations the elasticity of the first derivative of the adjustment cost of capital function ζ is set to the value implying the empirically observable relation between the volatilities of output and investment.

I ignore the autocorrelation structure of money supply process and assume that the percentage deviation of the growth factor of M_t from its long run level $\hat{\tau}_t$ follows a pure White Noise process whose standard deviation is identical with that of the unsystematic component of the money supply process, $\sigma_\tau = \sigma_u = 0.0092$. The estimation of σ_u is described in Appendix A. The total factor productivity is assumed to follow an AR(1) process also given in Appendix A.

Tables 1 summarizes the results obtained for the *Customer Markets Model*. The empirical second moments are taken from Hristov (2008b). It is readily seen that the model developed in this paper has two important shortcomings. First, it implies a large positive correlation between output and the markup. While as a reaction to a monetary innovation production and output tend to move in opposite directions, technological disturbances induce strong and persistent comovements of these variables. Obviously, the effects triggered off by technology shocks dominate. Second, the model performs very poorly with regard to the autocorrelation of inflation as well as its cross correlation with output. Nevertheless, the overall performance of the model should be seen as average with a slight tendency to understate the autocorrelations of most vari-

ables. After a large set of simulation exercises I concluded that the reactions to technology shocks are almost unaffected by variations in the parameter b . Hence any differences between the two specifications $b = 20$ and $b = 0.02$ present in Table 1 are largely due to the fact that the propagation of monetary disturbances is substantially affected by changes in b .³⁴

A comparison with the New Keynesian Model:

Table 2 contains the results from the *New Keynesian Model* obtained under the assumption of a relatively large degree of price stickiness, $\varphi = 0.75$. Values of b lower than 18 lead to very unrealistic model implications with regard to the volatilities of most macroeconomic variables. For that reason the comparison between the two models only refers to the case $b = 20$. The *New Keynesian Model* performs better than the one developed here with respect to the cross correlations with output of inflation and the markup. The latter equals 0.52 and is not far from its empirical counterpart, 0.317. The correlation between output and the markup is too high in magnitude but has the correct sign. In contrast the *Customer Markets Model* implies a negative correlation between output and inflation, -0.24, and a large positive one between output and the markup. Further, the predictions of the *New Keynesian Model* regarding the autocorrelations of the individual variables are *on average* closer to their respective empirical counterparts than it is the case in the *Customer Markets Model*. Nevertheless, the latter performs better with respect to the relative standard deviations of most variables as well as the cross correlations with output of all variables except inflation and the markup. Furthermore, the predictions of the *Customer Markets Model* with regard to the cyclical properties of the real wage match much better the empirical evidence than it is the case in the *New Keynesian Model*. The latter exhibits a drawback typical for most sticky price models - it substantially overstates the *relative* standard deviation

³⁴See also sections 5 and 7.

of the real wage.

Unfortunately, the careful inspection of the second moments of the two models does only reveal that each of them has as many important advantages as significant shortcomings. Therefore, neither model can be considered better than the other one.

Table 1: Theoretical and Empirical Second Moments (*Adjustment Costs of Capital Model*)

Variable	$sd(x)$	$sd(x)/sd(y)$	$acorr(x)$	$corr(x, y)$
Output				
$\zeta = -0.0348, b = 20$	1.20	1.00	0.68	1.00
$\zeta = -0.0070, b = 0.02$	1.22	1.00	0.69	1.00
US Data	1.547	1.000	0.863	1.000
Consumption				
$\zeta = -0.0348, b = 20$	1.16	0.96	0.65	0.94
$\zeta = -0.0070, b = 0.02$	0.95	0.78	0.70	0.98
US Data	0.697	0.451	0.889	0.735
Hours				
$\zeta = -0.0348, b = 20$	0.26	0.21	0.36	0.82
$\zeta = -0.0070, b = 0.02$	0.21	0.17	0.67	0.99
US Data	1.329	0.859	0.874	0.898
Real Wage				
$\zeta = -0.0348, b = 20$	0.43	0.35	0.13	0.61
$\zeta = -0.0070, b = 0.02$	0.23	0.19	0.67	0.99
US Data	0.815	0.527	0.637	0.472
Investment				
$\zeta = -0.0348, b = 20$	5.88	4.88	0.01	0.46
$\zeta = -0.0070, b = 0.02$	5.74	4.72	0.56	0.89
US Data	7.168	4.634	0.733	0.367
Real Balances				
$\zeta = -0.0348, b = 20$	1.08	0.90	0.66	0.66
$\zeta = -0.0070, b = 0.02$	0.04	0.03	0.58	0.61
US Data	3.222	2.083	0.941	0.280
Inflation				
$\zeta = -0.0348, b = 20$	1.06	0.88	0.01	-0.24
$\zeta = -0.0070, b = 0.02$	0.87	0.72	-0.06	0.01
US Data	0.387	0.250	0.497	0.317
Markups				
$\zeta = -0.0348, b = 20$	0.88	0.73	0.52	0.83
$\zeta = -0.0070, b = 0.02$	0.78	0.64	0.69	0.99
US Data	0.538	0.348	0.727	-0.058

$mu^* = 1.2, \theta = 0.2$, serially uncorrelated monetary shock $\sigma_\tau = \sigma_u = 0.0092$. ζ denotes the elasticity of $\phi' \left(\frac{I_t}{K_t} \right)$ with respect to I_t/K_t (see subsection 7.3). $sd(x)$ - standard deviation of x ; $sd(x)/sd(y)$ - ratio of the standard deviation of x to that of output; $acorr(x)$ - first order autocorrelation of x ; $corr(x, y)$ - contemporaneous correlation between x and output. The second moments refer to HP-filtered empirical and simulated data. The second moments implied by the model refer to averages over 300 simulations. Each simulated series consists of 135 observations.

Table 2: Theoretical and Empirical Second Moments (*New Keynesian Model with Adjustment Costs of Capital*)

Variable	$sd(x)$	$sd(x)/sd(y)$	$acorr(x)$	$corr(x, y)$
Output				
$\zeta = -0.057, b = 20$	1.56	1.00	0.80	1.00
$\zeta = -0.0085, b = 0.02$	5.61	1.00	0.10	1.00
US Data	1.547	1.000	0.863	1.000
Consumption				
$\zeta = -0.057, b = 20$	1.21	0.78	0.79	0.98
$\zeta = -0.0085, b = 0.02$	4.68	0.84	0.06	0.96
US Data	0.697	0.451	0.889	0.735
Hours				
$\zeta = -0.057, b = 20$	1.81	1.16	0.55	0.77
$\zeta = -0.0085, b = 0.02$	6.65	1.19	0.04	0.98
US Data	1.329	0.859	0.874	0.898
Real Wage				
$\zeta = -0.057, b = 20$	2.15	1.38	0.54	0.74
$\zeta = -0.0085, b = 0.02$	6.76	1.21	0.04	0.98
US Data	0.815	0.527	0.637	0.472
Investment				
$\zeta = -0.057, b = 20$	7.31	4.69	0.60	0.89
$\zeta = -0.0085, b = 0.02$	26.23	4.68	0.46	0.77
US Data	7.168	4.634	0.733	0.367
Real Balances				
$\zeta = -0.057, b = 20$	1.16	0.74	0.75	0.94
$\zeta = -0.0085, b = 0.02$	0.11	0.02	0.11	0.09
US Data	3.222	2.083	0.941	0.280
Inflation				
$\zeta = -0.057, b = 20$	0.60	0.39	0.46	0.52
$\zeta = -0.0085, b = 0.02$	0.78	0.14	0.03	0.95
US Data	0.387	0.250	0.497	0.317
Markups				
$\zeta = -0.057, b = 20$	2.97	1.91	0.48	-0.48
$\zeta = -0.0085, b = 0.02$	7.98	1.42	0.03	-0.95
US Data	0.538	0.348	0.727	-0.058

$\varphi = 0.75, mu^* = 1.2, \theta = 6$, serially uncorrelated monetary shock $\sigma_\tau = \sigma_u = 0.0092$. ζ denotes the elasticity of $\phi' \left(\frac{I_t}{K_t} \right)$ with respect to I_t/K_t (see subsection 7.3). $sd(x)$ - standard deviation of x ; $sd(x)/sd(y)$ - ratio of the standard deviation of x to that of output; $acorr(x)$ - first order autocorrelation of x ; $corr(x, y)$ - contemporaneous correlation between x and output. The second moments refer to HP-filtered empirical and simulated data. The second moments implied by the model refer to averages over 300 simulations. Each simulated series consists of 135 observations.

9 Conclusion

The model presented in this paper extends the standard monetary business cycles model with non-additively separable utility function and fully flexible prices by introducing market share competition and thus endogenizing markups. This new feature substantially improves the quantitative and qualitative properties of the model. In particular, positive monetary shocks become expansionary while the reactions of output, employment and real wages become delayed by one period, much as indicated by many VAR studies.

I also evaluate theory developed in this paper by comparing its implications with that of the *New Keynesian Model* with Calvo pricing. I conclude that the former should be considered a useful alternative to the latter for analyzing positive as well as normative issues. The model presented here also provides many dimensions along which it can be extended. For example by taking an explicit account of capital accumulation or labor market frictions.

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A Calibration

In models featuring static monopolistic competition the short run price elasticity of demand for an individual good θ is restricted to be greater than unity in order to ensure that the markup of prices over marginal costs is greater than one and thus profits are positive. Usually θ is set to a value between 6 and 8 since empirically observable average markups are relatively low - according to most estimations they are smaller than 1.6. In contrast to the static monopolistic competition model in the economies featuring market share competition described above one doesn't need to impose the restriction $\theta > 1$ since θ is not the sole determinant of the steady state markup mu^* . In fact, as I show below, any value of θ smaller than $\frac{mu^*}{mu^*-1}$ is consistent with $mu^* > 1$ and a negative first derivative of the function $g\left(\frac{P_{i,t}}{P_t}\right)$. A large part of the empirical evidence suggests that the short run price elasticity of demand for nondurables is well below one. Carrasco *et al.* (2005) provide panel estimates of the price elasticities of the demand for *food*, *transport* and *services* in Spain which take the values -0.85, -0.78 and -0.82 respectively. According to the results in Bryant and Wang (1990) based on aggregate US time series the price elasticity of *total demand for nondurables* is equal to -0.2078. Blanciforti *et al.* (1986) estimate an *Almost Ideal Demand System (AIDS)* based on aggregate US time series. Their results with respect to the own-price elasticities of nondurables can be summarized as follows: *food* - between -0.21 and -0.51; *alcohol and tobacco* - between -0.8 and -0.25; *utilities* - between -0.20 and -0.67; *transportation* - between -0.38 and -0.66; *medical care* - between -0.57 and -0.70; *other nondurable goods* - between -0.29 and -1.26; *other services* - between -0.20 and -0.36. There is also evidence supporting a short run price elasticity of demand greater than one. For example, using Finish time series Mellin and Viren (1982) come to the conclusion that the own-price elasticity of nondurables takes a value slightly below -5. However, their estimates should be interpreted with caution, since

they are most likely subject to a simultaneity bias. In a more recent paper Tellis (1988) surveys the estimates of the price elasticity of demand in the marketing literature. He provides a skewed distribution of the results found in that literature with mean, mode and standard deviation equal to -1.76, -1.5 and 1.74 respectively. The bulk of the estimated elasticities take values in the range $[-2,0]$. In light of the empirical evidence it appears more reasonable to set θ at a value lower than one. However, for the sake of completeness and better comparability with models featuring static monopolistic competition, I decide to carry out a sensitivity analysis with respect to θ by simulating the model for several values of θ below and several values above one.

Most authors set the steady state markup at a value in the range suggested by Rotemberg and Woodford (1993) - between 1.2 and 1.4. The same is done in the current paper - $mu^* = 1.2$ is chosen as a baseline value.

The distribution parameter appearing in the utility function a is set at 0.9 assigning a very high weight to consumption C_t and a very low one to money balances $\frac{M_t}{P_t}$. I vary the inverse of the elasticity of substitution between C_t and $\frac{M_t}{P_t}$, b , by setting it at values in the range $[0.02; 20]$.

The second part of the calibration involves finding the parameter values of γ and v as well as the steady state values C^* , K^* , I^* and π^* satisfying the economy's non-stochastic stationary equilibrium.

$\tau^* = 1$ implies that the steady state value of the gross rate of inflation is equal to one. To be able to determine the value of γ one needs to compute $\frac{\Omega^*}{D^*}$ first. To find the value of Ω^* just observe that the steady state is characterized by the following relationships $\Lambda_{t+1} = \Lambda_t$, $(\frac{P_t}{P})^* = 1$, $x_i^* = 1$ and $\frac{P_t}{P} - \mu^* = \frac{mu^*-1}{mu^*}$, and then insert them into the definition of Ω_t . After some algebraic manipulations one arrives at

$$\frac{\Omega^*}{D^*} = \frac{\beta}{1 - \beta} \frac{mu^* - 1}{mu^*}.$$

γ can then be derived from (16) evaluated at the steady state. This equation

is reproduced here for convenience:

$$mu^* = \frac{-\theta}{1 - \theta - \gamma \frac{\Omega^*}{D^*}}.$$

For γ to be positive θ should be smaller than $\frac{mu^*}{mu^*-1}$ which in the case $mu^* = 1.2$ is equivalent to the restriction $\theta < 6$. Next, in the models without capital, for a given value of N^* , C^* can be derived from the goods market equilibrium condition

$$Y^* = N^* = C^*.$$

The model featuring capital accumulation involves few additional calibration steps. The production elasticity of labor ω is chosen to satisfy the restriction:

$$\omega = mu^* \overline{\left(\frac{(W/P)N}{Y} \right)},$$

where $\overline{\left(\frac{(W/P)N}{Y} \right)}$ denotes the average actual labor share. The empirical estimates for this variable using US- as well as data for other industrialized countries vary between slightly below 0.6 and slightly below 0.8. I set labor share at the value estimated by Hristov (2008b). He applies the methods proposed by Cooley and Prescott (2005) to US data and comes to the conclusion that labor share equals 0.6747. The euler equation for optimal investment in capital (21) evaluated at the stationary equilibrium then implies

$$\frac{Y^*}{K^*} = mu^* \frac{1 - \beta(1 - v)}{\beta(1 - \omega)}.$$

By using this result together with the definition of the production function and a given N^* one arrives at:

$$K^* = \frac{N^*}{\left(\frac{Y^*}{K^*} \right)^{\frac{1}{\omega}}}.$$

The depreciation rate of capital v is also set at the value estimated by Hristov (2008b), 0.00708. In the next step the steady state value of investment I^* is easily derived via the law of motion for capital:

$$I^* = vK^*.$$

C^* star then follows from the aggregate resource constraint

$$C^* = Y^* - I^*.$$

There is only one additional parameter to be calibrated in the model with adjustment costs of capital³⁵ - the elasticity of $\phi\left(\frac{I_t}{K_t}\right)$ with respect to its argument I_t/K_t , denoted by ζ . Jerman (1998) provides a GMM estimate of ζ equal to -1/0.23. Unfortunately, in the models developed in the current paper that value implies that investment is less volatile than whereas the reverse is true in the industrialized world: For example, according to the computations performed in Hristov (2008b) in the USA investment is about 4,7 times as volatile as output. Therefore in subsection 7.3 ζ is chosen so that for a broad range of values of θ the model is able to replicate the empirically observable relation between the variability of output and that of investment.

I do not make an attempt to estimate the properties of the Solow-residual based on the current model since they would be strongly affected by the choice of the steady state markup mu^* , but borrow the estimates provided by Gomme and Rupert (2006) obtained with US-data. The process estimated by them takes the form

$$\ln(Z_t) = 0.9641 \ln(Z_{t-1}) + \epsilon_t, \tag{24}$$

where ϵ_t follows a White Noise process with standard deviation σ_ϵ equal to 0.0082. The implied unconditional standard deviation of the Solow-residual,

³⁵See subsection 7.3.

σ_z , is given by

$$\sigma_z = \frac{\sigma_\epsilon}{\sqrt{1 - 0.9641^2}} = 0.03088.$$

The properties of the money supply process were estimated by fitting an AR(p) process to the growth rate of the monetary aggregate M1. The process chosen by minimizing the *Akaike information criterion* is given by:³⁶

$$g_{M1,t} = 0.0037^{**} + 0.5097^{**} g_{M1,t-1} + 0.2251^{**} g_{M1,t-2} + \tilde{u}_t, \quad (25)$$

where $g_{M1,t}$ denotes the growth rate of M1,³⁷ \tilde{u}_t the residual term and ** indicates significance at the 5% level. The estimated standard deviation of the unsystematic component of money supply σ_u equals 0.0092. The unconditional mean and standard deviation of $g_{M1,t}$ take the values 0.0138 and 0.0125 respectively.

The subjective discount factor is set at 0.991 which is a *standard value* often found in the literature. ϕ is chosen to be consistent with the observable average fraction of time spent working N^* .³⁸ Table 3 summarizes the calibration of the model.

³⁶I used quarterly data from 1970:Q1 through 2003:Q3. According to the Ljung-Box-Q statistic and White's heteroscedasticity test the estimated residuals display neither serial correlation nor heteroscedasticity.

³⁷Note that the stochastic process generating $\tau_t = M_{t+1}/M_t$ introduced in section 4 can be identified as the AR(2) process in (25) since

$$g_{M1,t} = \ln(M_t) - \ln(M_{t-1}) = \ln(\tau_{t-1}).$$

³⁸See Hristov (2008b) for details about the calibration of N^* .

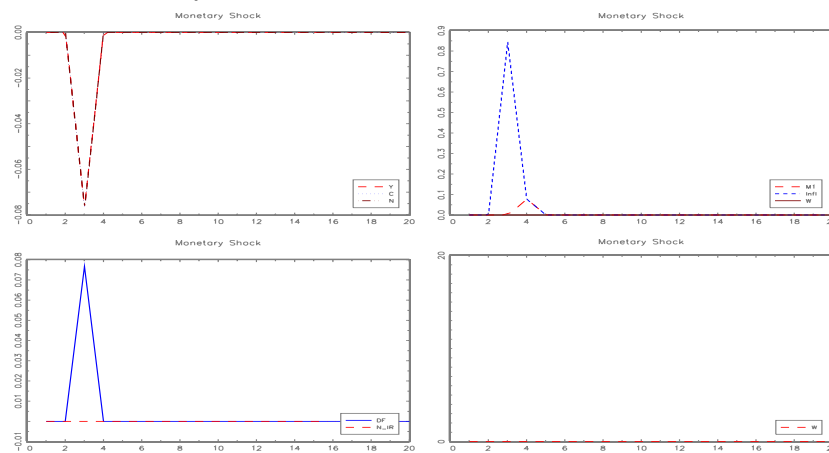
Table 3: Calibration

Households/Preferences	Firms/Technology	Central Bank
$a = 0.9$	$Z^* = 1$	$\tau^* = 1$
$b \in [0.02, 20]$	$\rho_z = 0.9641$	$\rho_\tau = 0$
$\beta = 0.991$	$\sigma_\epsilon = 0.0082$	$\sigma_u = 0.0092$
$\theta \in [0.2, 2.2]$	$mu^* \in [1.1; 1.4]$	
$N^* = 0.1386$	$\zeta > 0$, sensitivity analysis	

B A MIU-Model with Fixed Capital

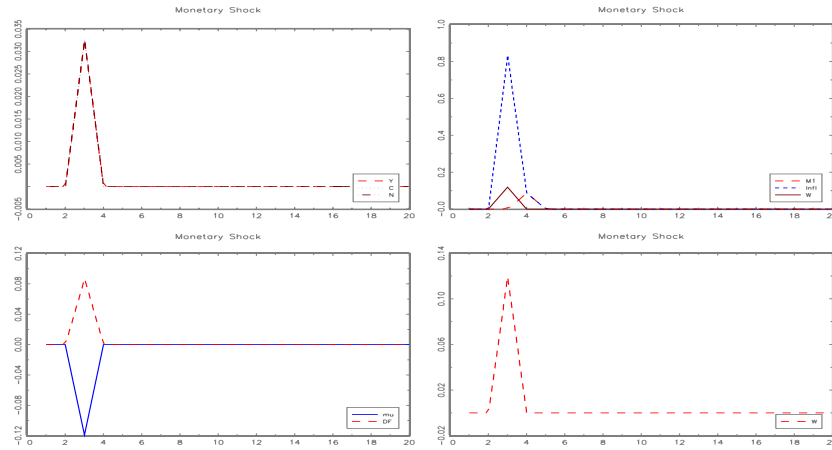
In each case the shock u_t in $\hat{\tau}_t = \rho_\tau \hat{\tau}_{t-1} + u_t$ takes place in the third period ($t = 3$) and equals one standard deviation σ_u .

Figure 1: MIU-model with fixed capital and no market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$. Percentage deviations from steady state.



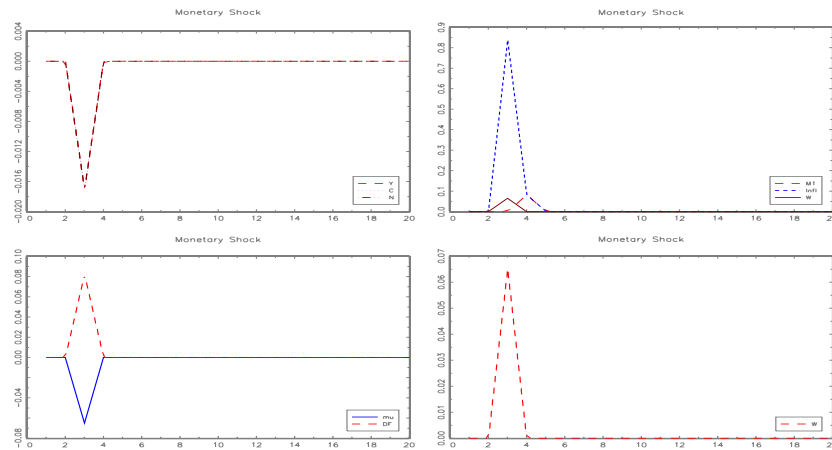
Y - output, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage.

Figure 2: MIU-model with fixed capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $\theta = 0.6$, $a = 0.9$, $b = 1$. Percentage deviations from steady state.



Y - output, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, mu - markup, Ω - expected present value of firm's profits.

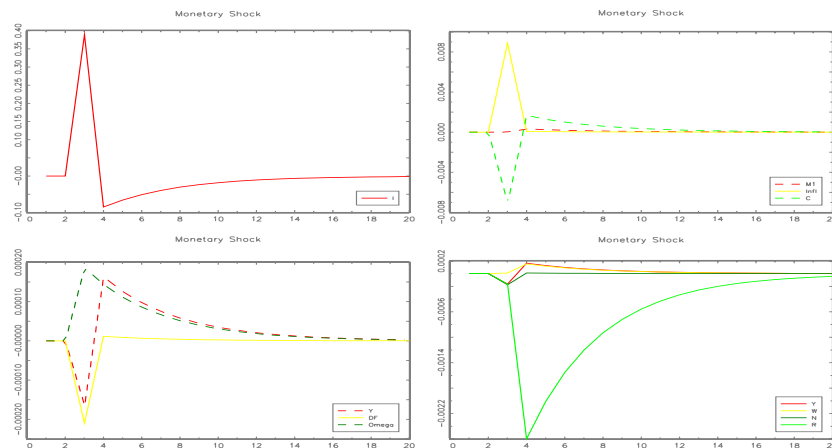
Figure 3: MIU-model with fixed capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $\theta = 1.4$, $a = 0.9$, $b = 1$. Percentage deviations from steady state.



Y - output, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, mu - markup, Ω - expected present value of firm's profits.

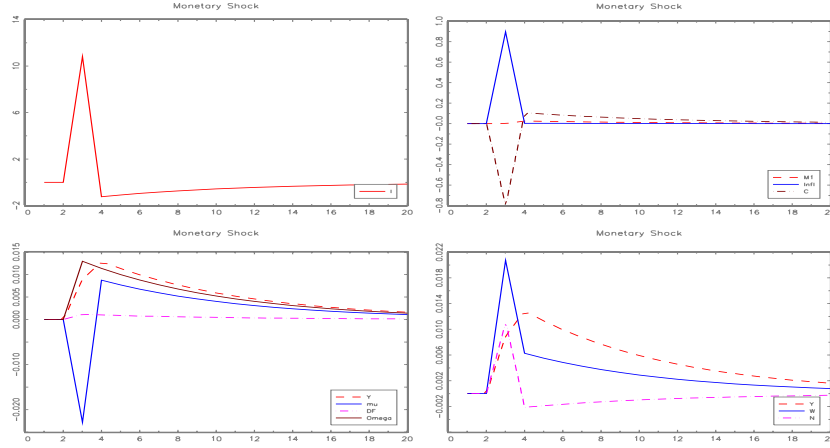
C A MIU-Model with Endogenous Capital

Figure 4: MIU-model with endogenous capital without market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $\theta = 6 \Rightarrow mu^* = 1.2$. Relative deviations from steady state.



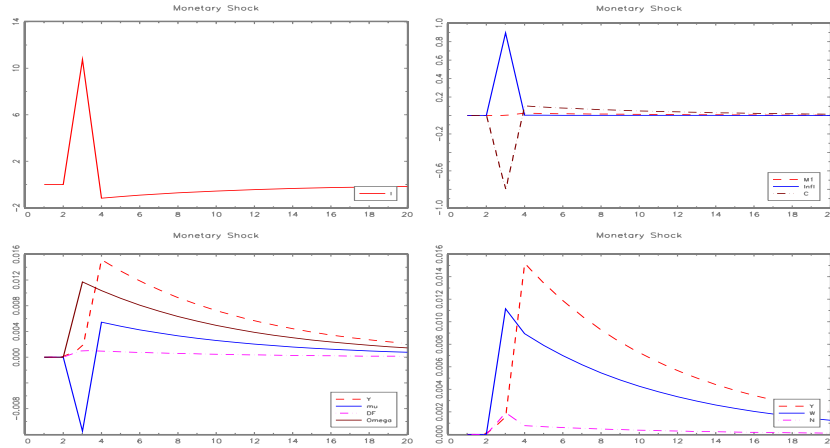
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, ir - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, R - real interest rate.

Figure 5: MIU-model with endogenous capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 0.2$. Percentage deviations from steady state.



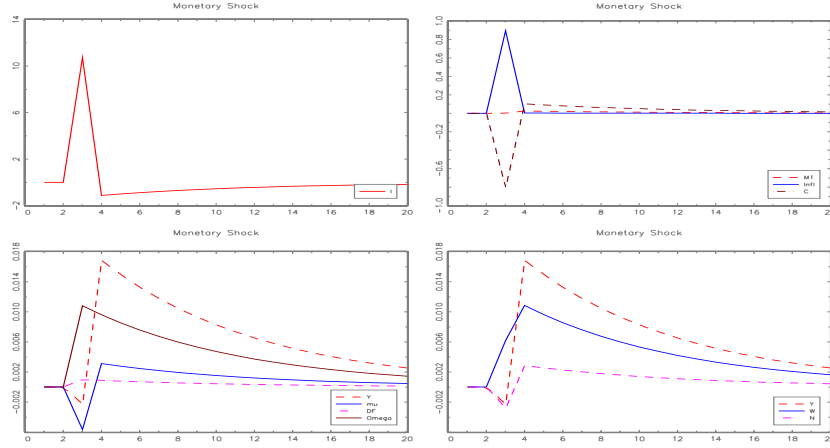
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 6: MIU-model with endogenous capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 0.9$. Percentage deviations from steady state.



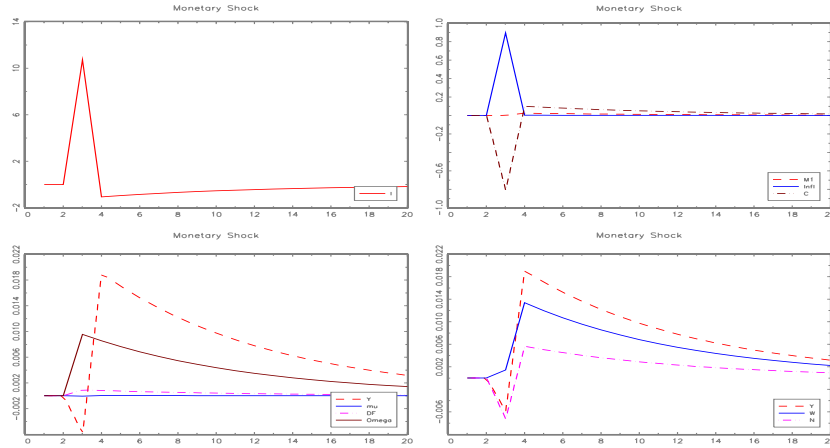
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 7: MIU-model with endogenous capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 1.9$. Percentage deviations from steady state.



Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

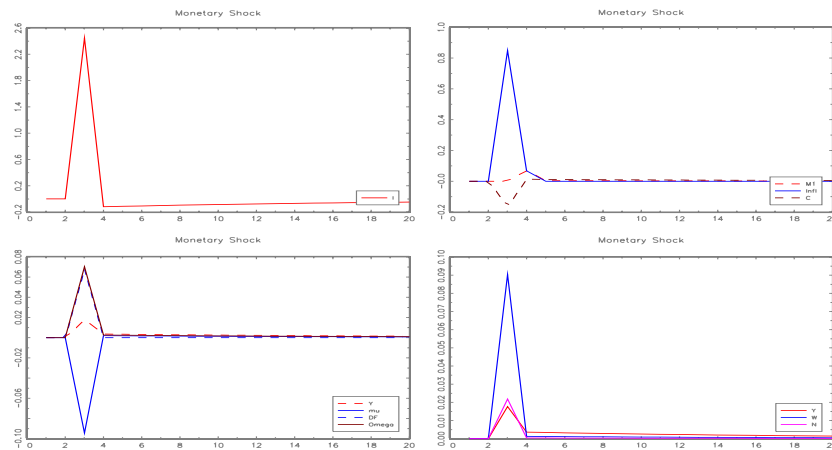
Figure 8: MIU-model with endogenous capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 5.9$. Percentage deviations from steady state.



Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

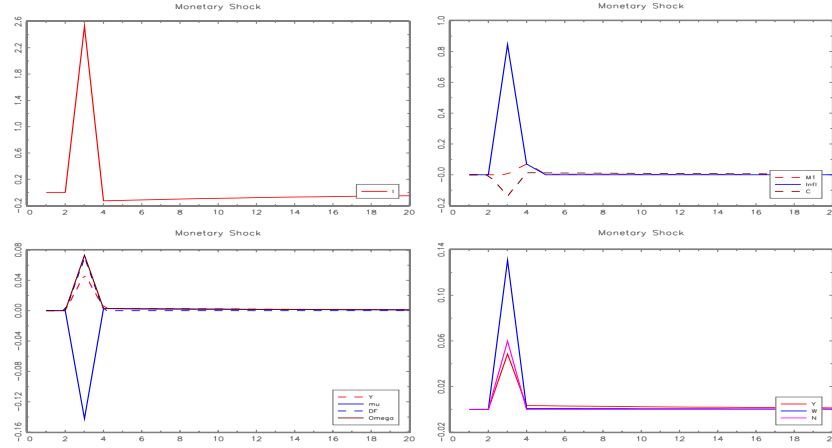
D A MIU-Model with Adjustment Costs of Capital

Figure 9: MIU-model with adjustment costs of capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 0.6$, $\zeta = -0.02607$. Percentage deviations from steady state.



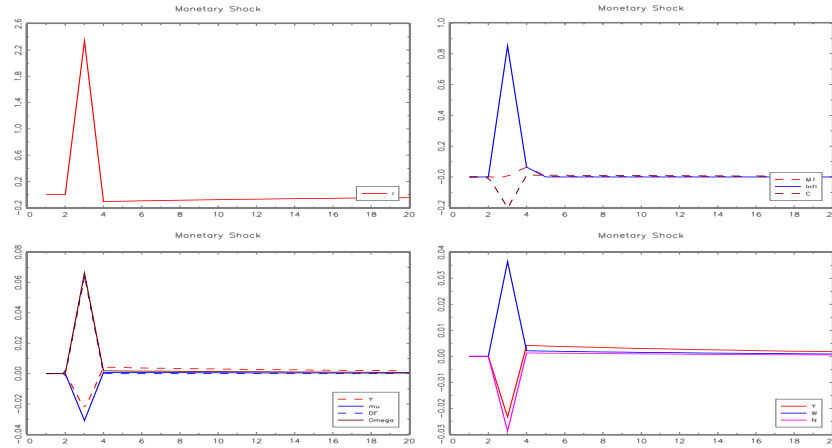
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 10: MIU-model with adjustment costs of capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 0.2$, $\zeta = -0.02607$. Percentage deviations from steady state.



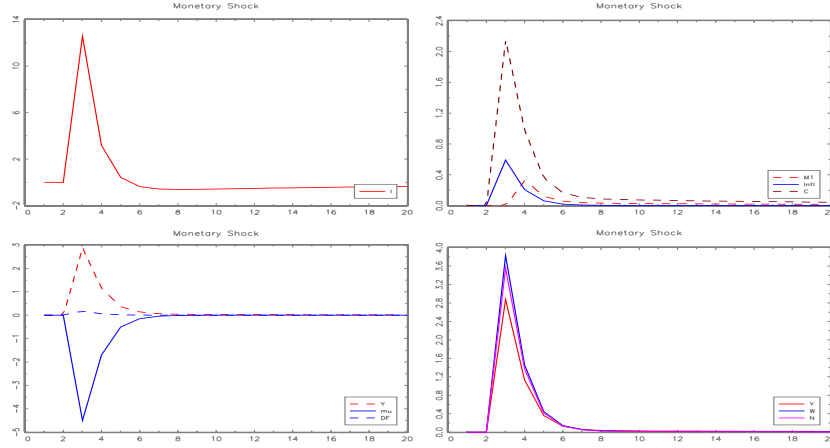
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 11: MIU-model with adjustment costs of capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 2.2$, $\zeta = -0.02607$. Percentage deviations from steady state.



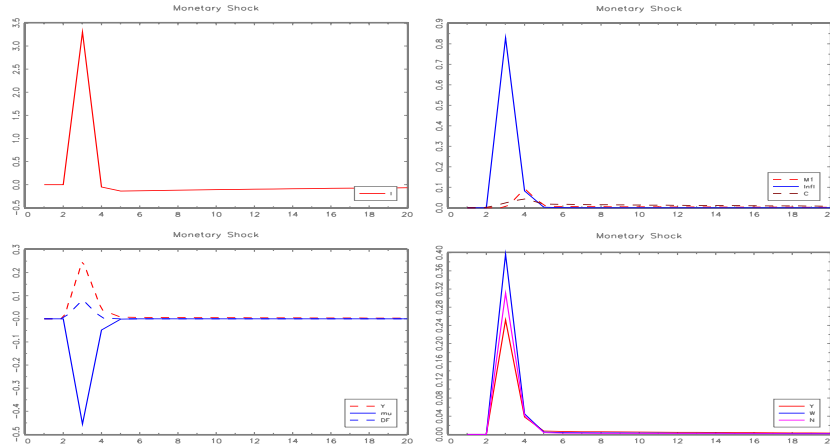
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 12: The *New Keynesian Model*. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 6$, $\varphi = 0.75$, $\zeta = -0.024$. Percentage deviations from steady state.



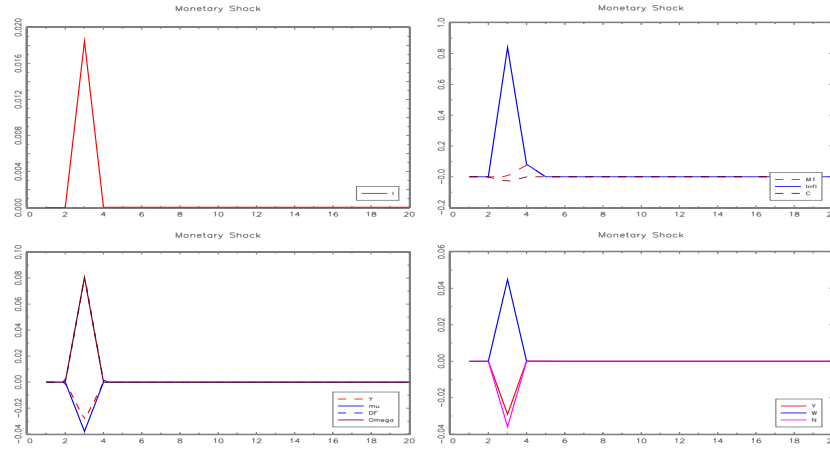
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $R - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 13: The *New Keynesian Model*. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 6$, $\varphi = 0.5$, $\zeta = -0.024$. Percentage deviations from steady state.



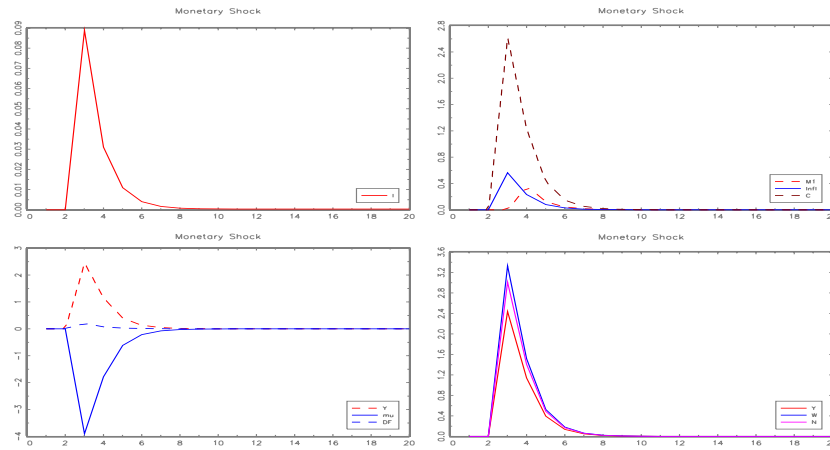
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $R - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 14: MIU-model with adjustment costs of capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 0.2$, $\zeta = -4.3478$. Percentage deviations from steady state.



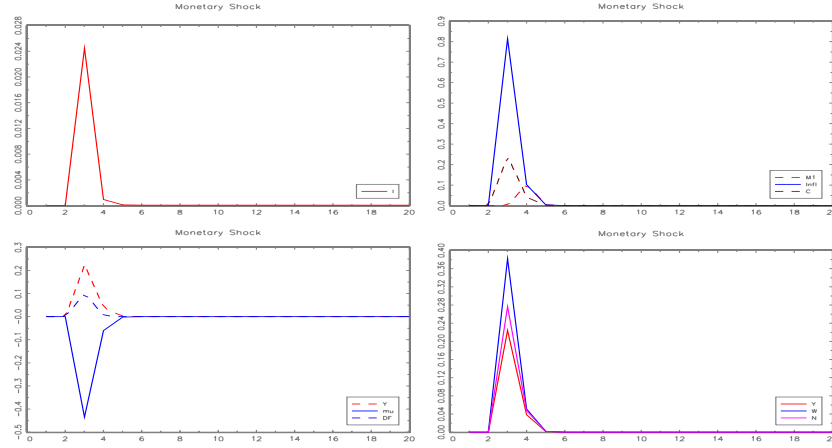
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 15: The *New Keynesian Model*. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 6$, $\varphi = 0.75$, $\zeta = -4.3478$. Percentage deviations from steady state.



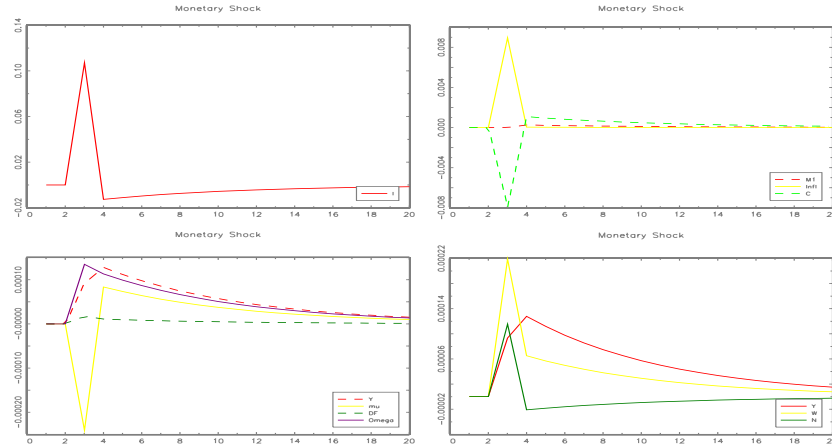
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 16: The *New Keynesian Model*. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 6$, $\varphi = 0.5$, $\zeta = -4.3478$. Percentage deviations from steady state.



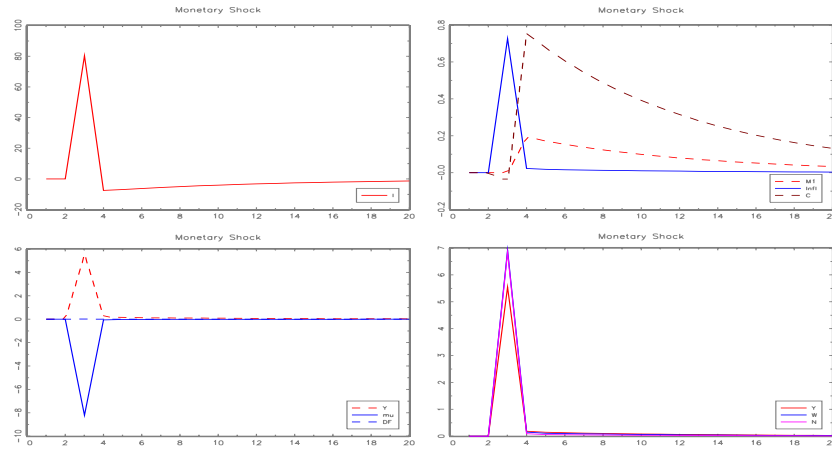
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 17: MIU-model with adjustment costs of capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 0.2$, $\zeta = -0.00004347$. Relative deviations from steady state.



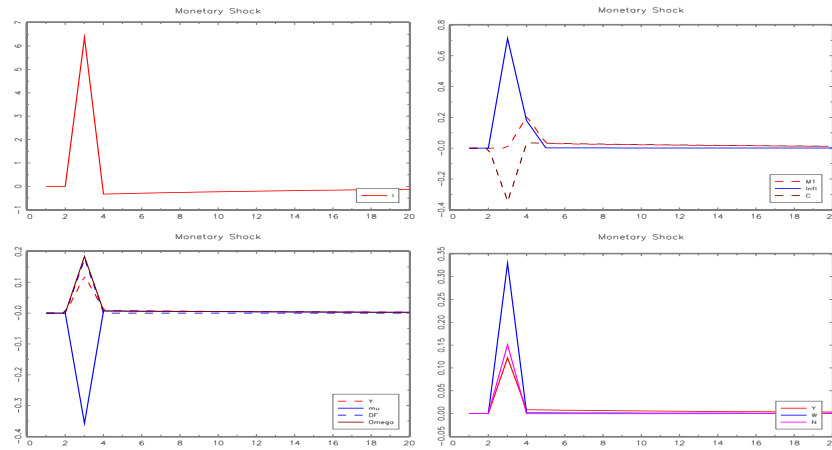
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 18: The *New Keynesian Model*. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 1$, $mu^* = 1.2$, $\theta = 6$, $\varphi = 0.75$, $\zeta = -0.00004347$. Percentage deviations from steady state.



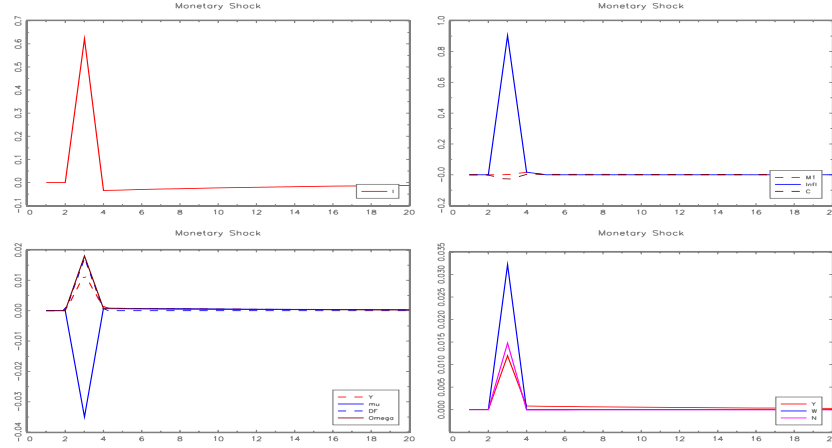
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 19: MIU-model with adjustment costs of capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 20$, $mu^* = 1.2$, $\theta = 0.2$, $\zeta = -0.02607$. Percentage deviations from steady state.



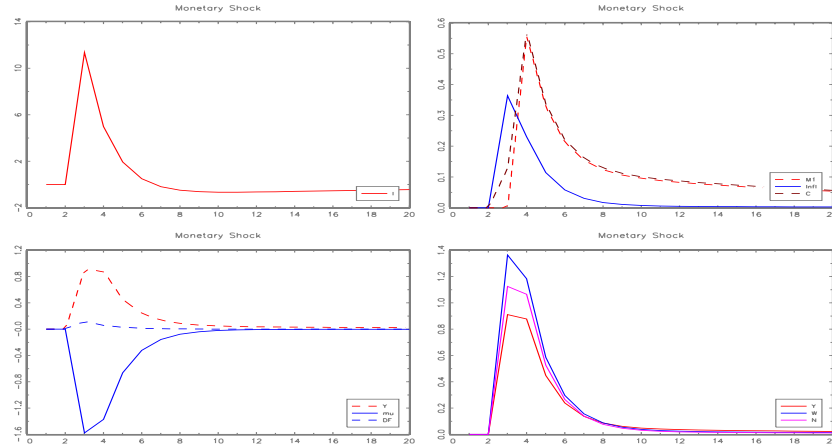
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 20: MIU-model with adjustment costs of capital and market share competition. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 0.02$, $mu^* = 1.2$, $\theta = 0.2$, $\zeta = -0.02607$. Percentage deviations from steady state.



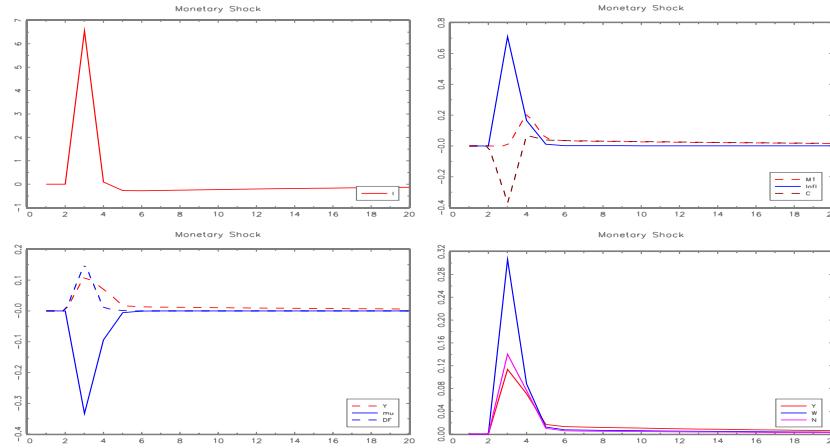
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 21: The *New Keynesian Model*. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 20$, $mu^* = 1.2$, $\theta = 6$, $\varphi = 0.75$, $\zeta = -0.024$. Percentage deviations from steady state.



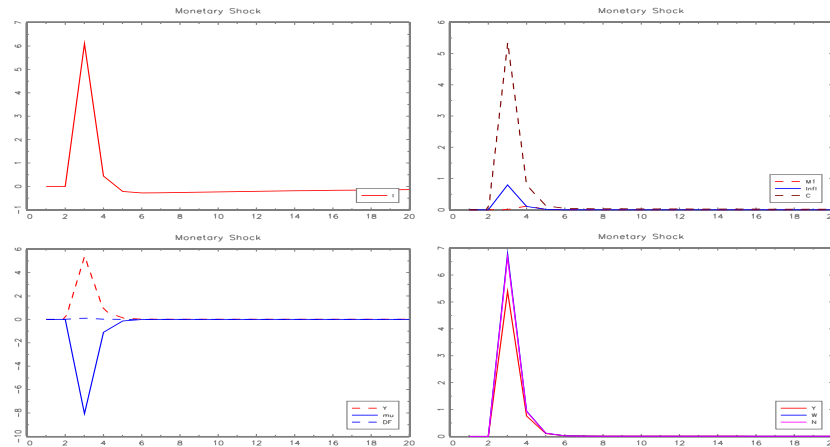
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 22: The *New Keynesian Model*. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 20$, $mu^* = 1.2$, $\theta = 6$, $\varphi = 0.5$, $\zeta = -0.024$. Percentage deviations from steady state.



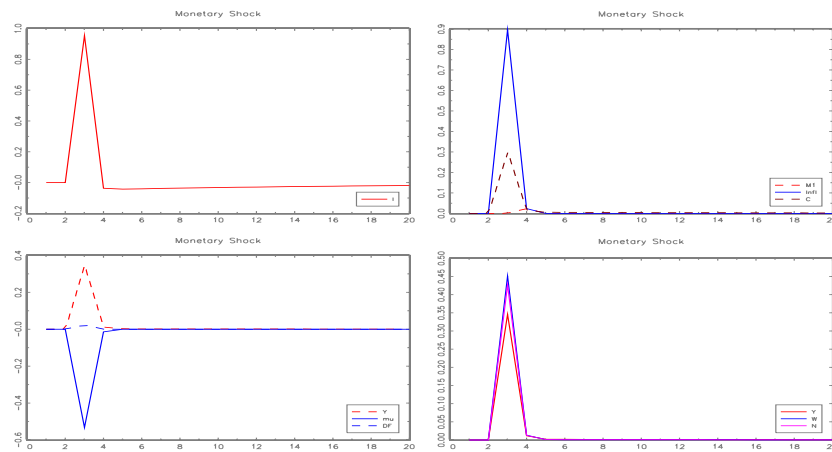
Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 23: The *New Keynesian Model*. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 0.02$, $mu^* = 1.2$, $\theta = 6$, $\varphi = 0.75$, $\zeta = -0.024$. Percentage deviations from steady state.



Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.

Figure 24: The *New Keynesian Model*. Impulse responses to a monetary shock, $\rho_\tau = 0$, $a = 0.9$, $b = 0.02$, $mu^* = 1.2$, $\theta = 6$, $\varphi = 0.5$, $\zeta = -0.024$. Percentage deviations from steady state.



Y - output, I - investment, N - hours, C - consumption, $M1 = \frac{M_t}{P_{t-1}}$ - real balances, $Infl$ - inflation, DF - discount factor, $N - ir$ - nominal interest rate, W - real wage, Ω - expected present value of firm's profits, mu - markup, R - real interest rate.