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Endogenous Inflation - The Role of Expectations and Strategic Interaction

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by

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Abstract

Macroeconomic fluctuations always are the result of complex interactive processes. For this reason, our challenge of the widely used New Keynesian Phillips Curve builds on Taylor's (1979) version, which provides room for a richer sequential and interactive structure. We show that the Taylor model can be fruitfully complemented by the assumption of a 'timeless' optimizing central bank. The macroeconomic equilibrium exhibits a significant degree of inflation inertia which is an endogenous economic result and not merely the consequence of exogenous persistence in aggregate real activity. This result is in stark contrast to earlier work by Kiley (2002) who found the New Keynesian Phillips curve to show more persistent reactions than its Taylor (1979) companion when being exposed to an exogenous monetary shocks.

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Following the seminal paper by Fuhrer and Moore (1995) a vast number of empirical studies showed that past inflation is an important and significant variable in explaining current inflation. In contrast, theoretical Phillips curve models derived from microeconomic principles relate current inflation only to future expected inflation as well as current and/or past excess demand but not to past inflation. If one takes such Phillips curve equations as a description of an independent economic relationship they tell us that the dynamics of inflation is autoregressive only to that degree to which is the excess demand, the main driving force.

The perspective of taking the Phillips curve independently of its economic environment, however, is hardly in line with the real economic world. In reality, aggregate supply (as desribed by the Phillips curve) is only one side of the economy which is not independent from its counterpart. Workers and capital owners for whose decision-making the Phillips curve is the stylized representation, are concerned about and confronted to aggregate demand conditions to which they react in an interactive way. In particular, workers and capital owners form expectations on future demand in the economy.

In order to cope with the interactive structure of an economy we try to endogenize inflation expectations which are a main variable in modern types of the Phillips curve. As economic counterpart we introduce a central bank which minimizes a social loss function characterized by the quadratic deviations from zero-inflation and steady-state growth. We pursue in that way in order to analyze the endogenous dynamics of inflation. The respective procedure, ie., dynamically optimizing the central bank's social welfare function while taking the Phillips curve as the respective constraint, is quite well-known in the monetary policy literature. For example, Svensson (1999) and Vestin (2001) used this method to compare different monetary policy strategies.

The purpose of this paper is a slightly different one. Instead of comparing two different policy strategies we analyse how the global model economy reacts on a structural variation of its supply side. Aggregate supply is most frequently represented by the standard New Keynesian Phillips curve (e.g., Gali (2002)) which describes current inflation as a function of merely current excess demand and future expected inflation. In contrast, Taylor (1979) provides a much simpler alternative. Taylor (1979)'s model is less general and only bases on a quasi-microfoundation. This simplicity, however, allows Taylor (1979) to abstain from approximations that ignore strategic interactions between individual price setters. As a consequence, Taylor (1979) provides a somewhat richer inflation dynamic than the standard New Keynesian Phillips curve. More precisely, in Taylor (1979) inflation depends also on past excess demand, not only on the current one and inflation expectations.

This seemingly small difference is of great consequence. A deviation of output from steady-state does not only alter current inflation but also causes disinflation in the next period to be costly. In addition, this future consequence is even anticipated in present time as being described by inflation expectations as explanatory variable. Therefore, we expect that this seemingly small modification by Taylor (1979) is important in an interactive perspective with endogenous central bank behavior.

Whereas the difference between the standard New Keynesian Phillips curve and the Taylor (1979) model already has been studied in respect to exogenous monetary shocks (Kiley 2002) we analyse the two different Phillips curve settings in a model economy with endogenous monetary policy. In this case of endogenous policy individuals, represented by either of the Phillips curves, anticipate that the central bank will minimize the social loss from inflation and unemployment in an intertemporal perspective. In other words, they do not merely react on exogenous events. We can show that, in contrast to Kiley (2002)'s work, the Taylor (1979) model turns out to endogenously produce more inflation inertia than the New Keynesian pendent.

The remainder of the paper is organized as follows: In the next section the two different versions of the Phillips curve are derived. The methodology will be explained in section 3 and applied to the two alternatives in sections 4 and 5. In section 6 the results are simulated and visualized. Section 7 concludes.

2. <u>Models of Aggregate Supply</u>

In the following section we derive the two slightly different types of Phillips curves from microeconomic principles. First, we describe the widely used New Keynesian Phillips curve. As we are interested in inflation dynamics, we concentrate on the price setting mechanism and leave out other aspects of decision-making. Secondly, we provide intuition for the Taylor (1979) type of nominal dynamics.

2.1 <u>The New Keynesian Phillips Curve</u>

The New Keynesian Phillips Curve is based on Calvo's (1983) model of partial price adjustment. Calvo (1983) assumes that firms adjust their prices infrequently. Furthermore, he assumes that opportunities to do so arrive according to an exogenous Poisson process where $(1-\omega)$ is the constant probability that a firm can adjust prices in the current period.

Rotemberg (1987) claims that representative firms i try to minimize the intertemporal sum of squared deviations of their (fixed) prices to the profit maximizing prices of the respective period. He shows that firms set prices according to

$$x_t = (1-\beta\omega)\sum_{j=0}^{\infty}\omega^j \beta^j E_t p*_{t+j} \tag{1}$$

where x_t is the price that is optimal for the adjusting firms, β is the discount factor representing time preference, ω the firm's probability of currently being inhibited from adjusting prices, and $E_t p*_{t+j}$ is the current expectation of the j period's ahead price level which would be profit-maximizing in the absence of any restrictions. Equation (1) describes the adjusted prices to be a weightened average of the current and future expected target prices $p*_{t+j}$. The currently adjusting firms' optimal price x_t can be rewritten as weightened average of the current target prices $p*_t$ and the expected optimal price of the following period's adjusting firms', $E_t x_{t+1}$,

$$x_t = (1-\beta\omega)p_t * + \omega\beta E_t x_{t+1}. \tag{1'}$$

Assuming that the target price level $p*_t$ depends on current output y_t as well as on the current aggregate price level p_t, equation (1') can be replaced by

$$x_t = (1-\beta\omega)(\gamma y_t + p_t + \nu_t) + \omega\beta E_t x_{t+1} \tag{1''}$$

where γ is a positive constant coefficient, depending on the goods' price elasticities of demand, and ν_t catches influences on pricing other than price level and aggregate demand. Hereby, $v_t = \rho\ v_{t-1} + \varepsilon_t$ is a stable first order stochastic process.

The dynamics of the aggregate price level, in turn, can approximately be described by

$$p_t = (1-\omega)x_t + \omega p_{t-1}. \tag{2}$$

if the number of firms is sufficiently large.

The equations (1'') and (2) can be reformulated and combined to describe the inflation dynamics of the model. If we take equation (2) and its one period's ahead expectations to eliminate x_t and $E_t x_{t+1}$ from equation (1'') we receive

$$\frac{1}{1-\omega}p_t - \frac{\omega}{1-\omega}p_{t-1} = (1-\beta\omega)(p_t + \gamma y_t + \nu_t) + \frac{\beta\omega}{1-\omega}E_t p_{t+1} - \frac{\beta\omega^2}{1-\omega}p_t \tag{3}$$

which can be rewritten as

$$\pi_t = \beta E_t \pi_{t+1} + \frac{(1-\omega)(1-\beta\omega)}{\omega}(\gamma y_t + \nu_t) \tag{3'}$$

as $\pi_t = p_t - p_{t-1}$. Simplifying notation, we get

$$\pi_t = \beta E_t \pi_{t+1} + 2ky_t + u_t \tag{3''}$$

where $2ky_t$ is intended to represent the current demand side effects[3] and $u_t = \rho\ u_{t-1} + \varepsilon_t$ all other, mainly the current supply side or cost push effects on inflation dynamics.

The derivation of this Calvo (1983) type of Phillips curve is based on critical assumptions. Especially equation (2) is an appropriate approximation of aggregate price dynamics only if excess demand varies just moderately and if the number of firms is large, i.e, if price setting of a single firm does not influence the aggregate price level and specific demand for another firm's good to a significant extend. If this is not the case the derived inflation dynamics lack of important strategic interaction effects. Furthermore, it is disputable to assume that the target price level, p^*_t depends on the actual price level, p_t, as the latter refers to an economy with pricing restrictions, the latter to one without restrictions. This assumption is necessary to receive (1'') from (1'). In any case, however, one has to think about eliminating the aggregate price level in equation (1'') by iteratively inserting the current and than lagged versions of equation (2). This procedure shows that price adjustment also depends on past values of excess demand. Altogether we see that, due to the sequential structure of the price setting process, the influence of past values on aggregate inflation is in line with the potential strategic effects mentioned above.

As Calvo's (1983) partial adjustment model can be solved only with approximations potentially disregarding strategic interaction effects we suggest to additionally analyse the

[3] In contrast to standard notation the effects of excess demand are normalized to $2ky_t$ instead of ky_t. This notation is comparable to the one of the Taylor (1979) model where $k(y_t+y_{t-1})$ represents demand side effects on inflation.

earlier and more simple Taylor (1979) model which does not compel to use approximation methods.

2.2 <u>The Taylor (1979) Model</u>

Instead of partial price adjustment, the Taylor (1979) model relies on the idea of an economy where two (types of) firms set alternately their prices. The sequential structure of the pricing decisions is deterministic. Firms set prices p_t in the way so that they cover the average of the contract wages x_t[4] which are valid at the stage plus a mark-up μ_t

$$p_t = \tfrac{1}{2}\left(x_t + x_{t-1}\right) + \mu_t \tag{4}$$

where variables represent log values and, for simplicity, the mark-up is set to $\mu_t=0$.

Workers orientate their wage aspiration on the current state of the business cycle, *yt*. As the expected real wage during the nominal wages contract period is $\frac{1}{2}[(x_t-p_t)+(x_t-E_t p_{t+1})]$ unions set nominal wages according to

$$x_t = \tfrac{1}{2}\left(p_t + E_t p_{t+1}\right) + \delta y_t \tag{5}$$

where δ is the wage elasticity of aggregate demand.

Inserting the wage setting equation (5) in the (simplified) price equation (4) we get

$$p_t = \tfrac{1}{4} p_t + \tfrac{1}{4} p_{t-1} + \tfrac{1}{4} E_t p_{t+1} + \tfrac{1}{4} p_t + \tfrac{1}{2}\delta y_t + \tfrac{1}{2}\delta y_{t-1}. \tag{6}$$

Subtracting $(\frac{3}{4} p_t + \frac{1}{4} p_{t-1})$ from equation (6), deviding the result by ¼, and noting that $\pi t=p_t-p_{t-1}$, we get

$$\pi_t = E_t \pi_{t+1} + 2\delta\left(y_t + y_{t-1}\right) \tag{6'}$$

To make equation (6') comparable to equation (3'') we discount the variables of the former to present time, simplify by taking $2\delta=k$, and add u_t to represent cost push effects on inflation

[4] In the Taylor (1979) model x_t represents the optimal nominal wage to be set by the workers or a union, repectively, whereas in the Calvo (1983) model it stands for the optimal price to set by the firm(s) in charge. As nominal wages in the former and nominal prices in the latter model are the respective microeconomic key variable, it is – in our case - not unprecise but economically appropriate to use the same label for them. In doing so, we are in line with standard notation.

$$\pi_t = \beta E_t \pi_{t+1} + k y_t + \beta^{-1} k y_{t-1} + u_t \qquad (6'')$$

where $u_t=\rho\ u_{t-1} + \varepsilon_t$, again, is a stable autoregressive process. The staggered price type of Phillips curve according to Taylor (1979) has a structure similar to the partial price adjustment one which follows from Calvo (1983).

3. Aggregate Demand: Optimal Central Bank Policy

As argued above, from our point of view it is not sufficient to appraise the two derived types of Phillips curve independently from demand side conditions. Aggregate demand is not given exogenously but depends on aggregate supply which we describe by the Phillips curve. Therefore we will evaluate the two derived types of Phillips curves by confronting them to aggregate demand which is governed by the central bank.

In line with the general course of action in the monetary policy literature we assume that the central bank minimizes a social loss function l_t which depends on inflation π_t and output y_t as nominal and real variable, respectively:

$$l_t = \tfrac{1}{2}\left(\pi_t^2 + \alpha y_t^2\right) \qquad (7)$$

The social loss is weightened sum of the squared deviation of (current) inflation π_t from price stability, $\pi_t=0$, and output y_t from its steady-state path where α is a positive coefficient. We assume that the central bank is perfectly able to control the aggregate output level y_t by its policy instruments while we, as usual, abstain from modelling the transmission process explicitly. Hereby, we also abstract from possible problems of the adoption of policy instruments.

Although most central banks are not exposed to directly binding restrictions in the conduct of their future monetary policy (Clarida, Gali, and Gertler 1999, p. 1971) we claim that the central bank does not pursue a discretionary policy. In contrast, we propose that the central bank adopts a policy strategy which is optimal over an infinite horizon. Moreover, we assume the central bank to take even a timeless perspective[5], i.e., to operate in a way that is not only optimal in respect to the future but also from the past point of view. This means that the central bank does not take individuals' price or wage setting decisions as given but punishes them if they did not adapt to its course of macroeconomic stabilization. In other

[5] For details on the ‚timeless perspective', see Jensen and McCallum, 2002.

words, the monetary authority pursues its strategy of intertemporally minimizing social loss *as if* it was already credible in previous periods. [6]

Speaking in formal terms, the central bank will dynamically optimize its loss function subject to the respective Phillips curve being the constraint.[7] Using Lagrangian, we get

$$L = -\tfrac{1}{2} E_t \left\{ \sum_{t=0}^{\infty} \beta^t \left[\left(\pi_t^2 + \alpha y_t^2 \right) + \phi_t F_t \right] \right\} \tag{8}$$

where $\frac{1}{2}\phi_t$ is the multiplier associated with the constraint at time t and F_t represents equation (3'') or (6''), respectively. Differentiating the Lagrangian to π_t and y_t and setting the results equal to zero, yields the optimal conditions. As will be shown in the next section the differentiation with respect to π_t provides different results for $t=0$ and $t>0$. This is the case because the expectations of present inflation, $E_{t-1}\pi_t$, have already been determined one period ago and, therefore are cancelled out when differentiating in respect to $t=0$. As the central bank is assumed to adopt a timeless perspective only the conditions for $t>0$ are applied and the results for $t=0$ are ignored.

4. Endogenous Inflation in a New Keynesian World

In this section we use the method described above and apply it to the case of the standard New Keynesian Phillips curve. With the Lagrangian being

$$L = -\tfrac{1}{2} E_t \left\{ \sum_{t=0}^{\infty} \beta^t \left[\left(\pi_t^2 + \alpha y_t^2 \right) + \phi_t \left(\pi_t - \beta \pi_{t+1} - 2k y_t - u_t \right) \right] \right\} \tag{8'}$$

the first order conditions result in

$$\pi_t = -\tfrac{1}{2}\phi_t, \qquad \forall t = 0 \tag{9.1}$$

$$\pi_t = -\tfrac{1}{2}\phi_t + \tfrac{1}{2}\phi_{t-1},, \qquad \forall t > 0 \tag{9.2}$$

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[6] For related problems of credibility and their possible solution, see, e.g., Walsh (2003), Chapter. 8.

[7] For methodological issues, see Currie and Levine (1993) and Woodford (1999).

$$y_t = \frac{k}{\alpha}\phi_t, \qquad \forall t \geq 0 \qquad (9.3)$$

Combining the first order conditions to eliminate the multiplier ϕ_t, we receive the conditions for the central bank's optimal policy

$$\pi_t = -\tfrac{1}{2}\frac{\alpha}{k}y_t, \qquad \forall t = 0 \qquad (10.1)$$

$$\pi_t = -\tfrac{1}{2}\frac{\alpha}{k}y_t + \tfrac{1}{2}\frac{\alpha}{k}y_{t-1}, \qquad \forall t > 0 \qquad (10.2)$$

As the central bank is conducting its monetary policy in a 'timeless' perspective, it will ignore the present time condition and act according to equation (10.2) from the very beginning. By rewriting as

$$\Delta y_t = -\frac{2k}{\alpha}\pi_t \qquad (10.2')$$

one can see that a 'timeless' central bank maximizes its welfare by *increasing* the output gap proportionally to current inflation. Hereby, the policy reaction will be the stronger the more effective a reduction in aggregate demand is for the reduction of inflation and the weaker the social preferences for real output are.

Inserting the optimal policy condition (10.2) into the Phillips curve yields a stochastic difference equation for y_t which describes the time path of excess demand as an endogenous policy result

$$y_t = \frac{\alpha}{2b_C}y_{t-1} + \frac{\alpha\beta}{2b_C}E_t y_{t+1} - \frac{k}{b_C}u_t \qquad (11)$$

where $b_c \equiv ½\alpha(1+\beta)+2k^2$. The stable solution of (11) is

$$y_t = \eta_{C1}y_{t-1} + \eta_{C2}u_t \qquad (12)$$

with

$$\eta_{C1} \equiv \frac{b_{C1} - \sqrt{b_{C1}^2 - \alpha^2 \beta}}{\alpha\beta} \equiv \frac{\frac{1}{2}\alpha(1+\beta) + 2k^2 - \sqrt{\frac{1}{4}\alpha^2(1+\beta)^2 + 2\alpha k^2(1+\beta) + 4k^4 - \alpha^2\beta}}{\alpha\beta}$$

and

$$\eta_{C2} \equiv \frac{2k}{\alpha\beta\eta_{C1} + \alpha\beta\rho - 2b_{C1}} \equiv \frac{2k}{\alpha\beta\eta_{C1} + \alpha\beta\rho - \alpha(1+\beta) - 4k^2}$$

as $\eta_{C1} \in (0,1)$. This result, in turn, can be combined with the optimality condition (10.2) which yields the endogenous inflation dynamics, resulting from the interactions on the macroeconomic level

$$\pi_t = \eta_{C1}\pi_{t-1} - \frac{\alpha}{2k}\eta_{C2}(u_t - u_{t-1}) \tag{13}$$

or

$$\begin{aligned}\pi_t = {} & \frac{\frac{1}{2}\alpha(1+\beta) + 2k^2 - \sqrt{\frac{1}{4}\alpha^2(1+\beta)^2 + 2\alpha k^2(1+\beta) + 4k^4 - \alpha^2\beta}}{\alpha\beta}\pi_{t-1} \\ & - \frac{1}{\beta\eta_{C1} + \beta\rho - (1+\beta) - \frac{4}{\alpha}k^2}(u_t - u_{t-1})\end{aligned} \tag{13'}$$

Thus, in a New Keynesian world inflation turns out to be a stable AR(1)-process with an *increase* in the cost pressure, i.e., $\Delta u_t > 0$, driving current inflation upwards (as $\eta_{C2} < 0$).

5. Endogenous Inflation in a Taylor-Type Economy

After having derived the endogenous results for the New Keynesian benchmark, we proceede in the same way for an economy in which prices are set in line with Taylor (1979). From the modified Lagrangian

$$L = -\tfrac{1}{2}E_t\left\{\sum_{t=0}^{\infty}\beta^t\left[\left(\pi_t^2 + \alpha y_t^2\right) + \phi_t\left(\pi_t - \beta\pi_{t+1} - ky_t - ky_{t-1} - u_t\right)\right]\right\} \tag{14}$$

the first order conditions are derived which are the same for $\frac{\partial L}{\partial \pi_t} = 0$ as in the New Keynesian economy

$$\pi_t = -\tfrac{1}{2}\phi_t, \qquad \forall t = 0 \qquad (15.1)$$

$$\pi_t = -\tfrac{1}{2}\phi_t + \tfrac{1}{2}\phi_{t-1},, \qquad \forall t > 0 \qquad (15.2)$$

but differ for $\dfrac{\partial L}{\partial y_t} = 0$

$$y_t = \frac{k}{2\alpha}\phi_{t+1} + \frac{k}{2\alpha}\phi_t, \qquad \forall t \geq 0 \qquad (15.3)$$

Concentrating on the relevant case of a 'timeless' monetary policy strategy, we get the optimal condition

$$\tfrac{1}{2}\left(\pi_t + E_t\pi_{t+1}\right) = -\tfrac{1}{2}\frac{\alpha}{k}y_t + \tfrac{1}{2}\frac{\alpha}{k}y_{t-1},, \qquad \forall t > 0 \qquad (16)$$

or

$$\Delta y_t = -\frac{k}{\alpha}\left(\pi_t + E_t\pi_{t+1}\right) \qquad (16')$$

Compared to the New Keynesian benchmark case (equation 10.2'), an optimally working central bank will react on average half a period earlier on inflation (and even process inflation expectations) when it is confronted with Taylor-type price setters (equation 16').

By inserting the optimal policy condition (16) into the aggregate supply equation following from Taylor (1979), we, again, get a stochastic difference equation describing the endogenous time path for y_t

$$y_t = \frac{\alpha - \beta^{-1}k^2}{b_T}y_{t-1} + \frac{\alpha\beta - k^2}{b_T}E_t y_{t+1} - \frac{k}{b_T}E_t u_{t+1} - \frac{k}{b_T}u_t \qquad (17)$$

where $b_T \equiv \alpha(1+\beta)+k^2\beta^{-1}(1+\beta)$ and $E_t u_{t+1} = \rho u_t$. For appropriate parameter[8] values the difference equation (17) yields a single stable solution which is

[8] For a time discount factor $\beta = 0,96$ (assumed contract lenght: 1 year) $\eta_{T1} \in (0; 1)$ if $k \in (0,144; 0,939)$. If the central bank has no time preference, $\beta = 1$, there is always a single and stable solution for all positiv values of k, however, $\eta_{T1} > 0$ only for $k < 1$.

$$y_t = \eta_{T1} y_{t-1} + \eta_{T2} u_t \tag{18}$$

with

$$\eta_{T1} \equiv \frac{b_{T1} - \sqrt{b_{T1}^2 - 4\alpha^2\beta + 8\alpha k^2 - \beta^{-1}k^4}}{2(\alpha\beta - k^2)} \equiv$$

$$\frac{\alpha(1+\beta) + k^2\beta^{-1}(1+\beta) - \sqrt{\alpha^2(1+\beta)^2 + 2\alpha\beta^{-1}k^2(1+\beta)^2 + k^4\beta^{-2}(1+\beta)^2 - 4\alpha^2\beta + 8\alpha k^2 - \beta^{-1}k^4}}{2(\alpha\beta - k^2)}$$

and

$$\eta_{T2} \equiv \frac{k(1+\rho)}{\alpha\eta_{T1} + \alpha\rho - b_{T1}} \equiv \frac{k(1+\rho)}{\alpha\eta_{T1} + \alpha\rho - \alpha(1+\beta) - k^2\beta^{-1}(1+\beta)}.$$

To determine the endogenous dynamics of inflation, we substitute out y_t from (18) by inserting the optimal policy (16), and we receive

$$\pi_t = (\eta_{T1} - 1)\pi_{t-1} + \eta_{T1}\pi_{t-2} - \frac{\alpha}{k}\eta_{T2}(u_{t-1} - u_{t-2}). \tag{19}$$

In the Taylor (1979) world the endogenous time path of inflation depends on lagged inflation and the previous period's change in cost push pressure. For $(\eta_{T1}\text{-}1)<0$ the previous period's inflation has a *deflationary* influence on the current period but increases inflation, again, another period later. An *increase* in the cost pressure fuels inflation with a lag of one period. In contrast, in the New Keynesian world (equation 13) lagged inflation increases current inflation and only in the next period; the inflationary effect of an increase in cost pressure occurs without delay.

The mentioned results are surprising at first glance. As an optimally operating central bank in a Taylor (1979) economy (equation 16') is partly forward-looking and fights inflation on average half a period earlier than in a New Keynesian economy (equation 10.2') one might expect that endogenous inflation depends on shorter lags in the former case. Equations (13) and (19), however, show the opposite. As a central bank in the Taylor (1979) economy knows that a current reduction in excess demand reduces inflation also in the following period, it will apply its policy instruments in a more careful and temporarily extended way than a central bank in a New Keynesian economy. In the latter environment aggregate demand directly influences inflation only in the current period. In both cases the policy effects are reinforced by the forward-looking behavior of the price or wage setters. Clear predictions, however, are hard to derive from the analytical solution which depends on a bundle of parameters. This fact reflects the high complexity of a macroeconomic system in which a forward-looking central bank interacts with forward-looking agents in an economy with overlapping contracts. Therefore, in the next section the results are simulated for a broad range of parameter values.

6. Simulation Results

In this section we will conduct impulse response exercises to get a more precise idea how output and inflation evolve endogenously in reaction to a cost push shock of size 1% of its equilibrium value. Thereby, we proceed in the following way: First, we explain the simulation exercise and describe the results for the Taylor (1979) economy. Secondly, we compare the results to that of a New Keynesian economy and give some explanations for the observed differences. Thirdly, we briefly refer to variations in the parameters in order to show that the obtained results are robust for a broad parameter range.

Starting point of the simulation is an economy in equilibrium[9] and in absence of shocks. In period 1 the cost push term is increase by 1% over its equilibrium value. The values for inflation and excess demand are computed for the next 10 periods by using the respective solutions for the endogenous time path:

Taylor economy:

$$y_t = \eta_{T1} y_{t-1} + \eta_{T2} u_t \tag{18}$$

$$\tilde{\pi}_t = (\eta_{T1} - 1)\pi_{t-1} + \eta_{T1}\pi_{t-2} - \frac{\alpha}{k}\eta_{T2}(u_{t-1} - u_{t-2}) +/- \bar{\pi}^* \tag{19'}$$

$$\pi_t^{\text{int}} = \tilde{\pi}_t - k(y_t + y_{t-1}) \tag{19''}$$

New Keynesian economy:

$$y_t = \eta_{C1} y_{t-1} + \eta_{C2} u_t \tag{12}$$

$$\pi_t = \eta_{C1}\pi_{t-1} - \frac{\alpha}{2k}\eta_{C2}(u_t - u_{t-1}) \tag{13}$$

$$\pi_t^{\text{int}} = \pi_t - 2ky_t \tag{19''}$$

[9] I.e., log-values of inflation and excess demand are zero.

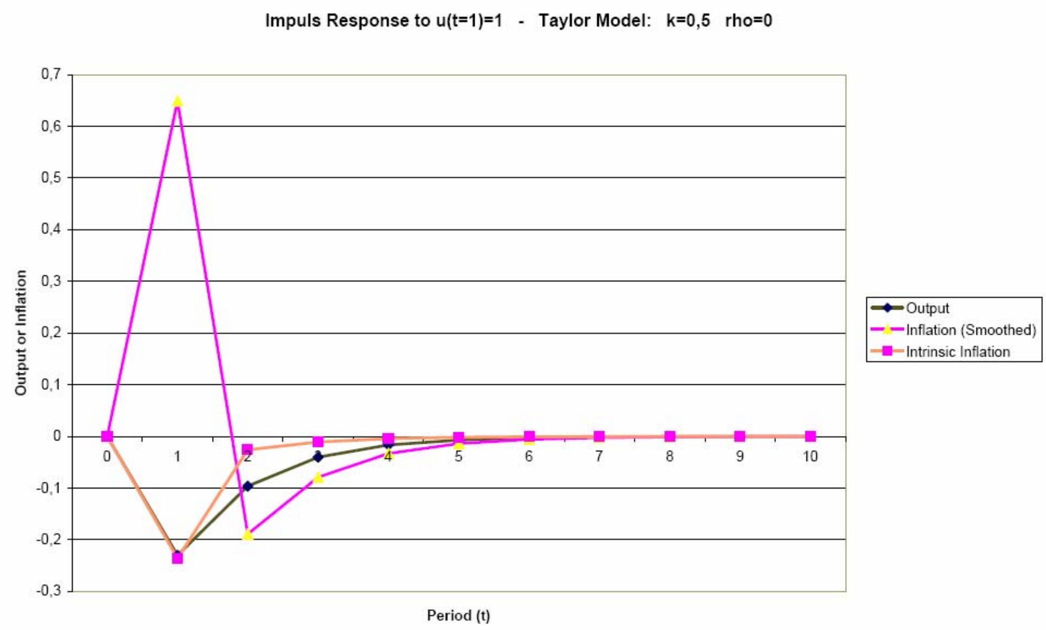
where π_t^{int} is the intrinsic inflation, i.e., this fraction of inflation that is due to intrinsic inflation persistence and not merely caused by excess demand or a cost push shock.

A special issue is endogenous inflation in the Taylor (1979) economy (equation 19). In this particular case the analytically precise inflation dynamics are dominated by a cycling pattern. This cycling effect is due to the overlapping structure of the Taylor (1979) model and the only stylized microfoundations of its agents (equation 4 and 5). In order to stress the medium term business cycle aspects of the model economy the somewhat artificial cycling component is removed. This smoothing procedure is done by subtracting the steady-state amplitude of the cycling component, $\bar{\pi}^*$.

As standard setting we fix the relevant parameters as follows: The central bank's relative preference for aggregate output compared to price stability is $\alpha = 1$. The discount factor evaluating time preference is $\beta = 0.96$, therefore, the corresponding rate of time preference is 4% per period. The responsiveness coefficient of inflation on excess demand which inversely reflects the market power of the price or wage setters is $k = 0.5$. Finally, the cost push shock is assumed not to show autocorrelation, $\rho = 0$, in the standard case.

Black lines show the time path of output, purple lines describe the dynamics of inflation or smoothed inflation, respectively, whereas orange lines represent the purely intrinsic inflation. Solid lines are the endogenous outcome of the Taylor economy, dashed lines refer to the New Keynesian world.

As we see in figure 1, in the Taylor (1979) world the central bank immediately fights against the inflationary pressure of the cost push shock taking place in period 1. This is done by the reduction of aggregate output, i.e., by creating an output gap. This output gap is smoothly reduced in the subsequent periods and, provided that there is no further supply side shock, converges to its steady-state. Smoothed inflation is increased as a consequence of the initial cost push . However, this effect is partially offset by the lack of aggregate demand as intended by the monetary authority. Due to the sluggish influence of excess demand on production the initial rise of prices is reverted to deflation before the state of price stability is approached again. Intrinsic inflation which is driven by future inflation expectations is pushed to its negative range as a deflationary policy reaction on the cost push is correctly anticipated by price setters. From then on also intrinsic inflation converges back to its equilibrium path. Output gap and (negative) intrinsic inflation have influence on smoothed inflation to a comparable degree.

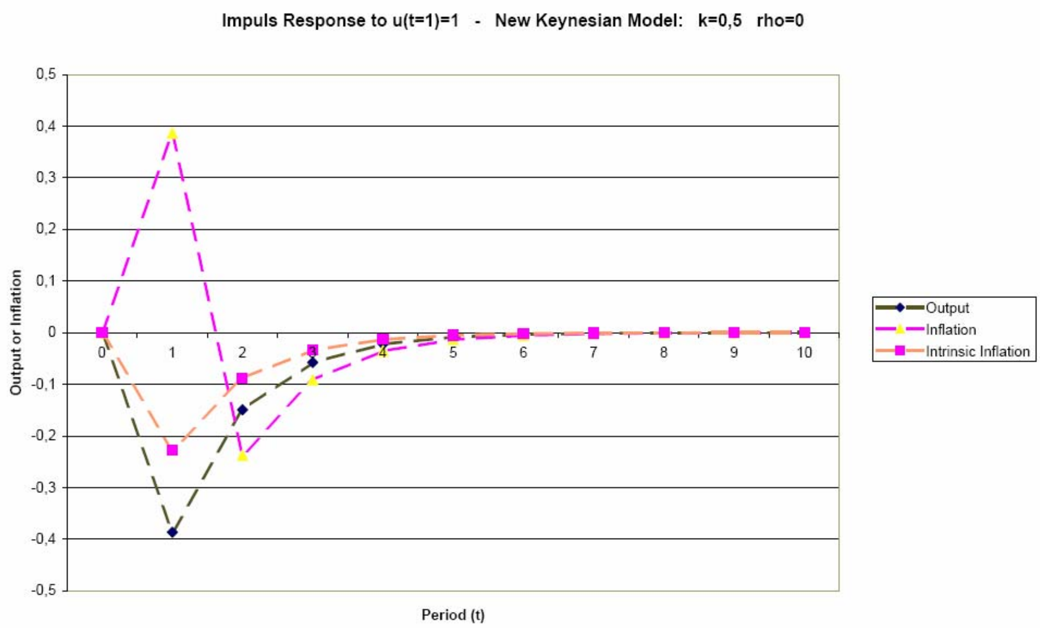


<u>Figure 1:</u> Impuls Response to u(t=1)=1; Taylor (1979) Model : k=0,5 rho=0.

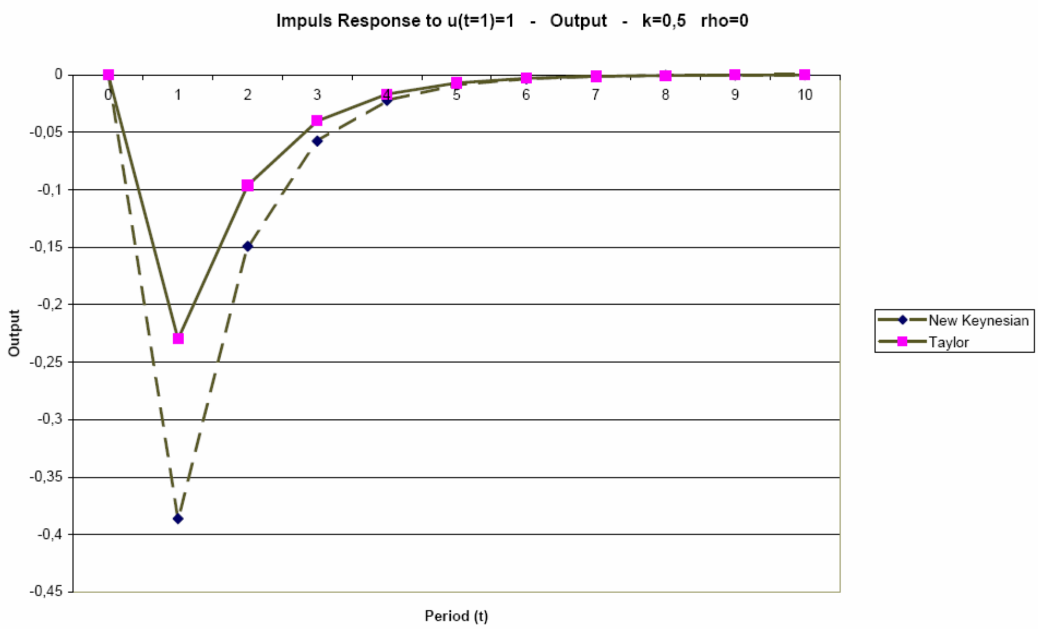
Figure 2 shows that in the New Keynesian world the endogenous reactions of output and inflation on the cost push shock are similar to that of the Taylor (1979) economy. Only the amplitude of inflation seems to be smaller in the New Keynesian case. For details, however, let us directly compare the respective variables.

Figure 3 shows how the central bank reduces output in response to a cost push shock. The policy action is clearly stronger in the New Keynesian case. This in line with our predictions. A Taylor (1979) world central bank more carefully reduces excess demand knowing that this reduction will have the same inflation reducing effects in the next as in the current period.

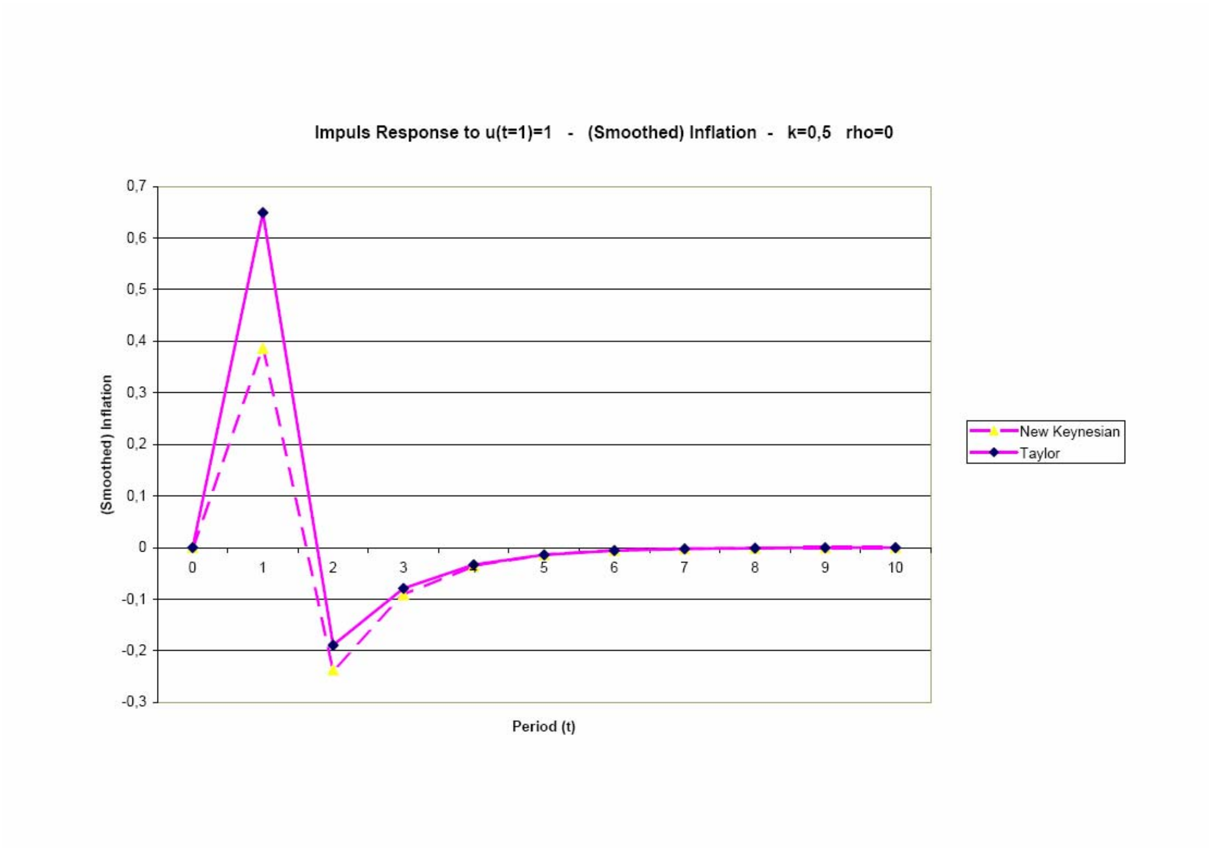
Inflation dynamics has a similar structure in both type of economies as figure 4 shows. In the Taylor (1979) economy, however, the central bank leaves more room to shift the cost push shock into prices. Consequently, deflation in the subsequent period has a somewhat minor extend. The results for inflation are in line with what we have learned about the different output dynamics of both economies.



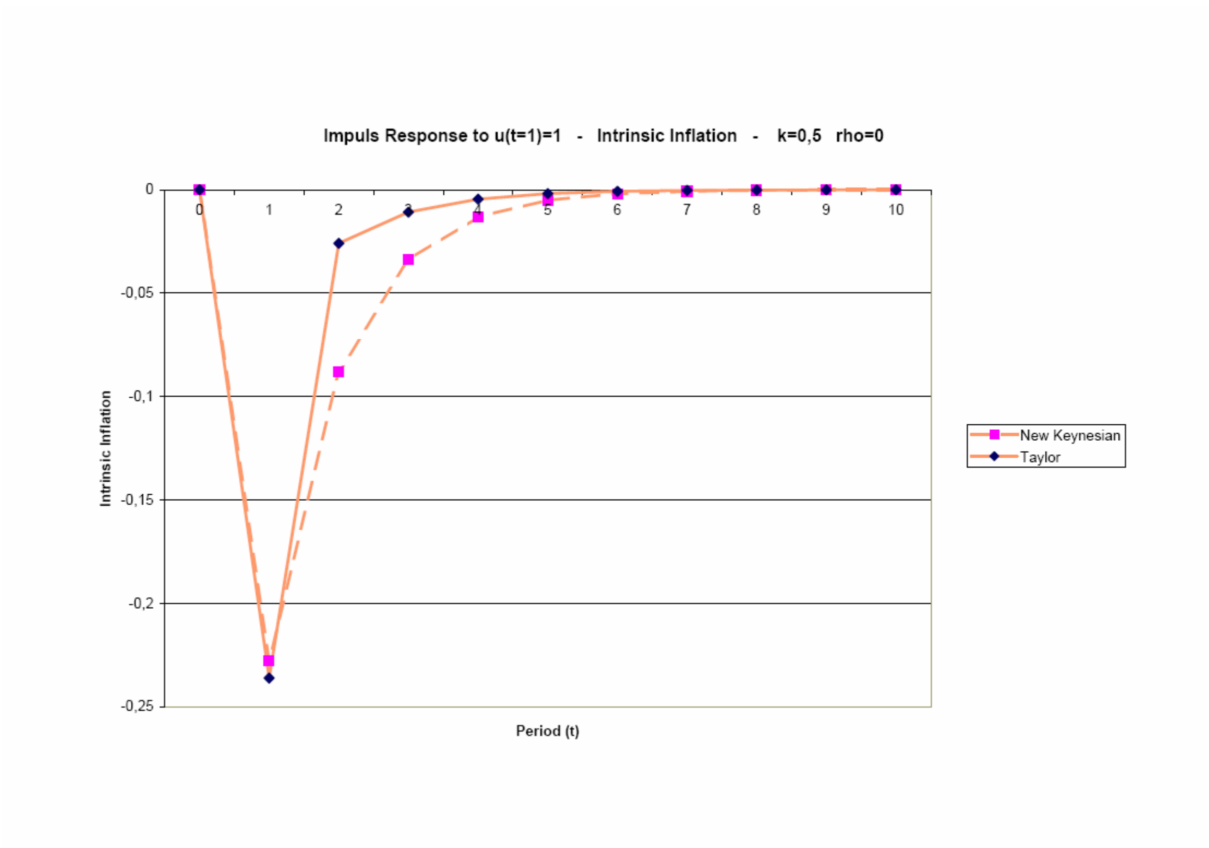
<u>Figure 2:</u> Impulse Response to u(t=1)=1; Taylor/New Keynesian PC: k=0,5; rho=0.



<u>Figure 3:</u> Response of Output to u(t=1)=1; Taylor/New Keynesian PC: k=0,5; rho=0.



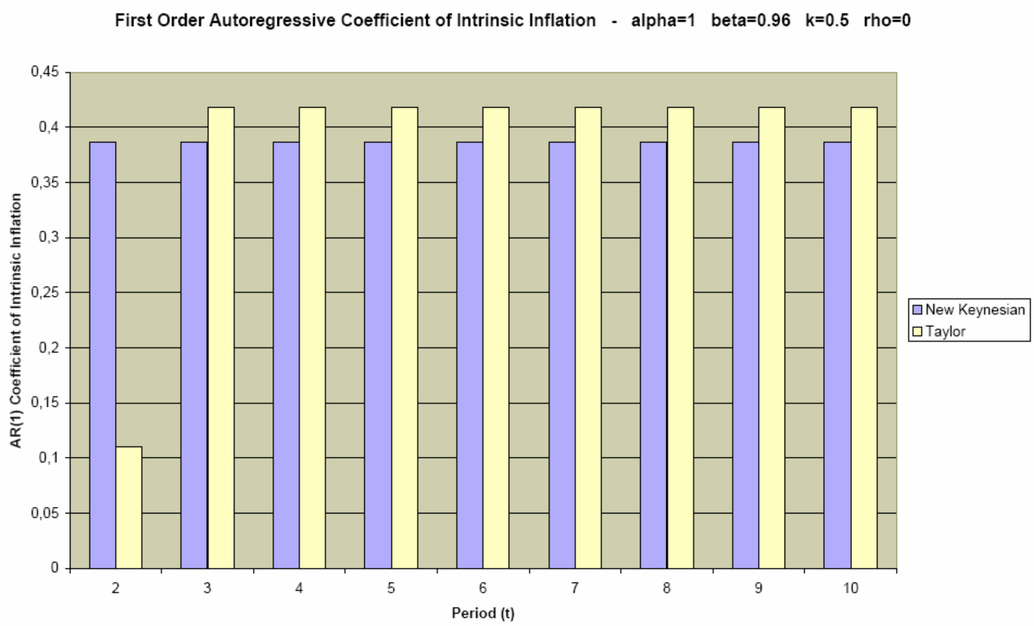
<u>Figure 4:</u> Response of Inflation to u(t=1)=1; Taylor/New Keynesian PC: k=0,5; rho=0.



<u>Figure 5:</u> Response of Intrinsic Inflation to u(t=1)=1; Taylor/New Keynesian PC.

So, are differences in inflation dynamics only the direct result of different output reactions in the two economies? Figure 5 shows that in both economies intrinsic inflation, being neither due to excess demand nor cost push but solely being driven by expectations, increases in a similar way when a cost push shock occured. In contrast, intrinsic inflation converges more smoothly back to equilibrium in the New Keynesian world. To better understand this fact we will consider the autocorrelation of intrinsic inflation.

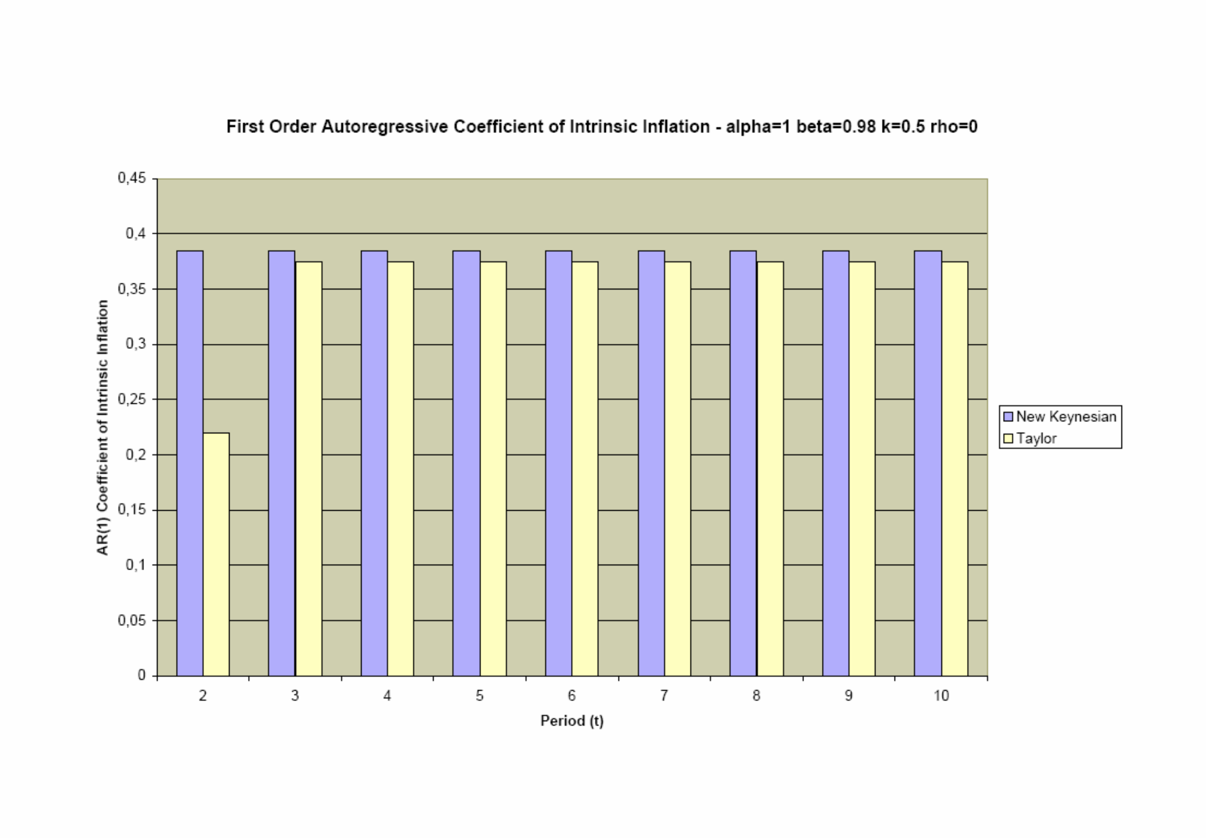
Figure 6 shows the autoregressive coefficients of intrinsic inflation. The blue columns represent the New Keynesian economy, the yellow ones are the results in the Taylor (1979) world. We find that autoregression of intrinsic inflation is higher in the Taylor (1979) world, even if only to a small but constant extend. The only exception of this fact we find in period 2. Here, the Taylor (1979) economy shows by far a much smaller degree of autoregression than the New Keynesian economy, even a smaller than oneself in the following periods. This effect can be explained by the additional output lag in the Taylor (1979) type Phillips curve. Price setters know that the reduction in excess demand, pursued to fight cost push inflation, will dampen prices also in the second but not anymore in the third period. Consequently, inflation expectations are already reduced in period 2. One can resume that the Taylor (1979) type Phillips curve, due to its extra lag, is one period in delay in getting the turn-around back to equilibrium.



<u>Figure 6:</u> Autoregression of Intrinsic Inflation - α=1, β=0,96, k=0,5, ρ=0.

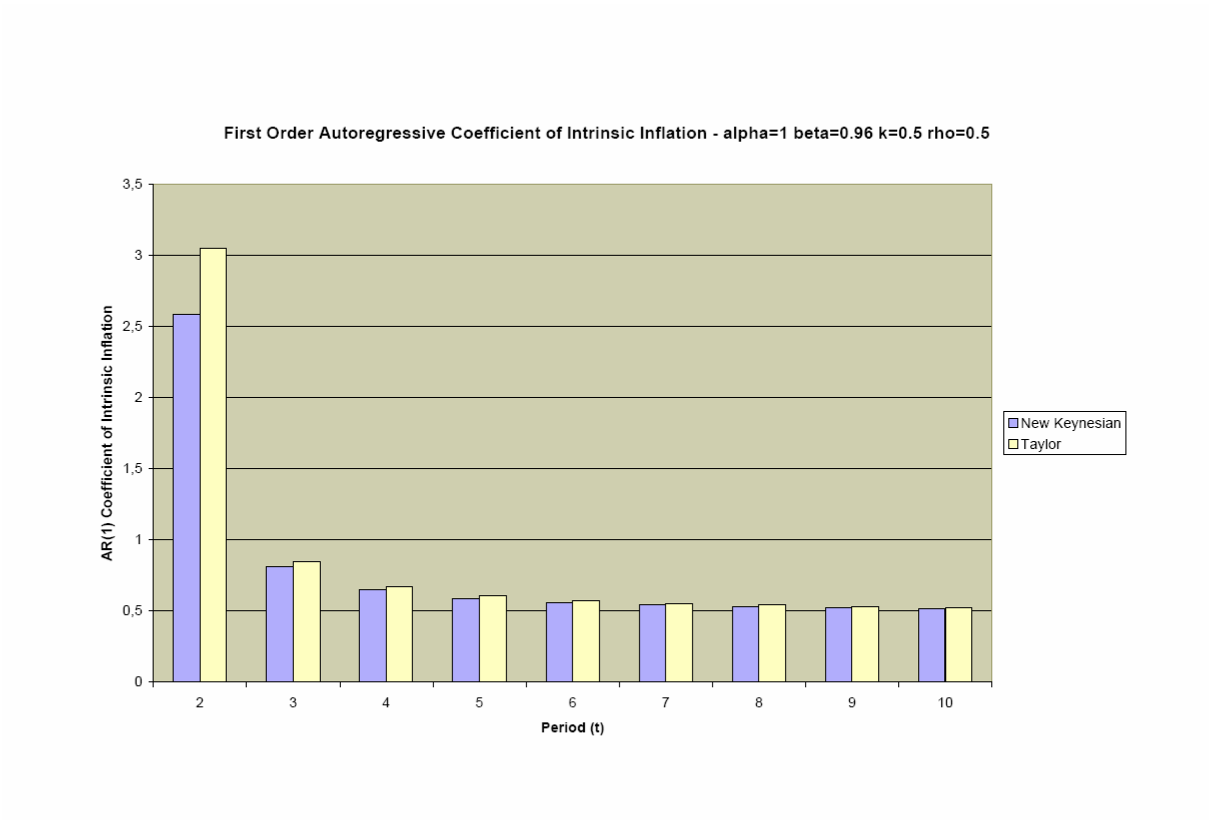
But is what we observe in figure 6 a general result? In order to see whether the finding that the Taylor (1979) economy experiences a higher degree of intrinsic inflation persistence might only be due to the specific parameterization we vary each of the main four parameters (α=0.5, α=2; β=0.94, β=0,98; k=0.2, k=0.8; ρ=0.5). Thereby, we keep the other three parameters constant. As result we see that the levels vary in the parameters, however, the structure of the endogenous dynamics mainly remains unchanges. For the sake of clarity we refer to the Appendix where we have moved to the respective figures.

One major exception from finding qualitatively unchanged results is the case of a time preference parameter of $\beta = 0{,}98$. Figure 7 shows that when time preference is low autoregression is little higher in the New Keynesian than in the Taylor (1979) case. As individuals with low time preference evaluate future events lower than present or even past ones, the lagged output term of the Taylor type Phillips curve receives a higher weight. This might be the reason why in the presence of low time preference a Taylor (1979) economy converges especially fast to equilibrium.



<u>Figure 7:</u> Autoregression of Intrinsic Inflation - α=1, β=0,98, k=0,5, ρ=0.

Remarkable is also the endogenous outcome for an autocorrelated cost push shock (*ρ=0.5*). Figure 8 exhibits that the autocorrelation coefficient of intrinsic inflation is not constant over time. It is high directly after the occurrence of the cost push shock and then converges to the value of its shock autocorrelation. The latter, however, does not prevent a Taylor (1979) economy from experiencing higher inflation persistence than the New Keynesian one.



<u>Figure 8:</u> Autoregression of Intrinsic Inflation - α=1, β=0,96, k=0,5, ρ=0.5.

7. <u>Conclusions</u>

Nominal as well as real macroeconomic fluctuations are always the result of complex interactive processes. For this reason we challenged the widely used New Keynesian Phillips Curve by incorporating into our model the (seemingly more simple) version developed by Taylor (1979). The simpler approach, however, proved to provide more room for a richer sequential and interactive structure. Exposing the Taylor (1979) model to a timeless optimizing central bank, we are able to reproduce a significant degree of inflation inertia which is endogenous in the spirit of an interactive economy and not merely the consequence of exogenous persistence in real output.

We pursued our analysis in the perspective of an endogenous economic system. Thereby, we amended earlier work by Kiley (2002) who also considered the New Keynesian Phillips curve and its Taylor (1979) companion. In contrast to our approach, Kiley (2002) represented the economy's demand side by exogenous monetary shocks which, of course, do not depend on price and wage setters' behavior. Thus, in his approach inflation is a direct response to exogenous shocks, whereas in our case the path of inflation is determined by a goal-oriented central bank which tries to offset undesirable exogenous shocks. Insofar, it is not surprising that Kiley (2002) finds the New Keynesian Phillips curve to create more inflation persistence than the Taylor (1979) model, whereas we – for most parameters values – came to the opposite result.

A better knowledge about causes and characteristics of inflation persistence is necessary for a precise, target-oriented monetary policy. Therefore, we carried out simulations to disentangle cost push, aggregate demand and inflation expectations as distinct sources of inflation inertia and to get an impression of their relative importance. The major insight from our model, however, is more general: Strategic interaction, prevalent between the central bank and price setters as well as among price setters, is a major candidate to explain intrinsic inflation persistence.

Appendix:

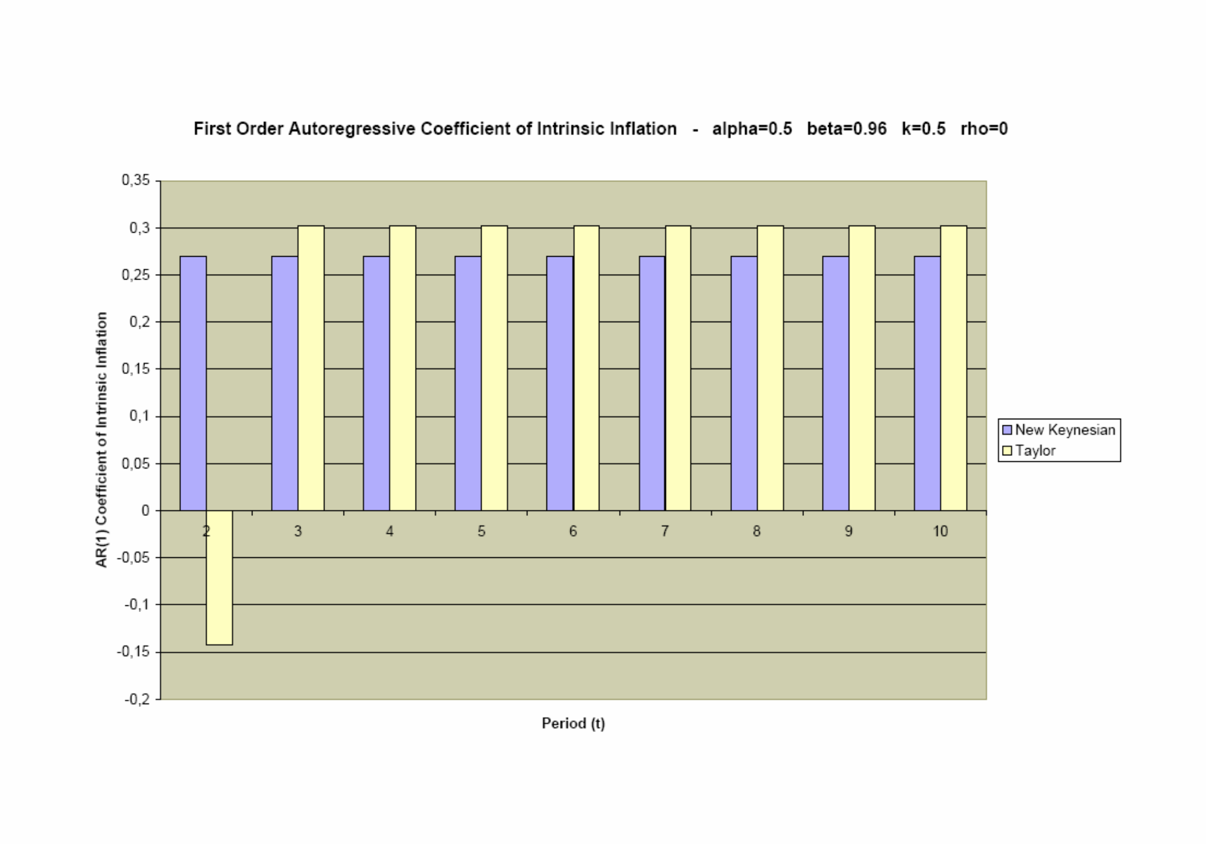


Figure 9: **Autoregression of Intrinsic Inflation - α=0.5, β=0,96, k=0,5, ρ=0.**

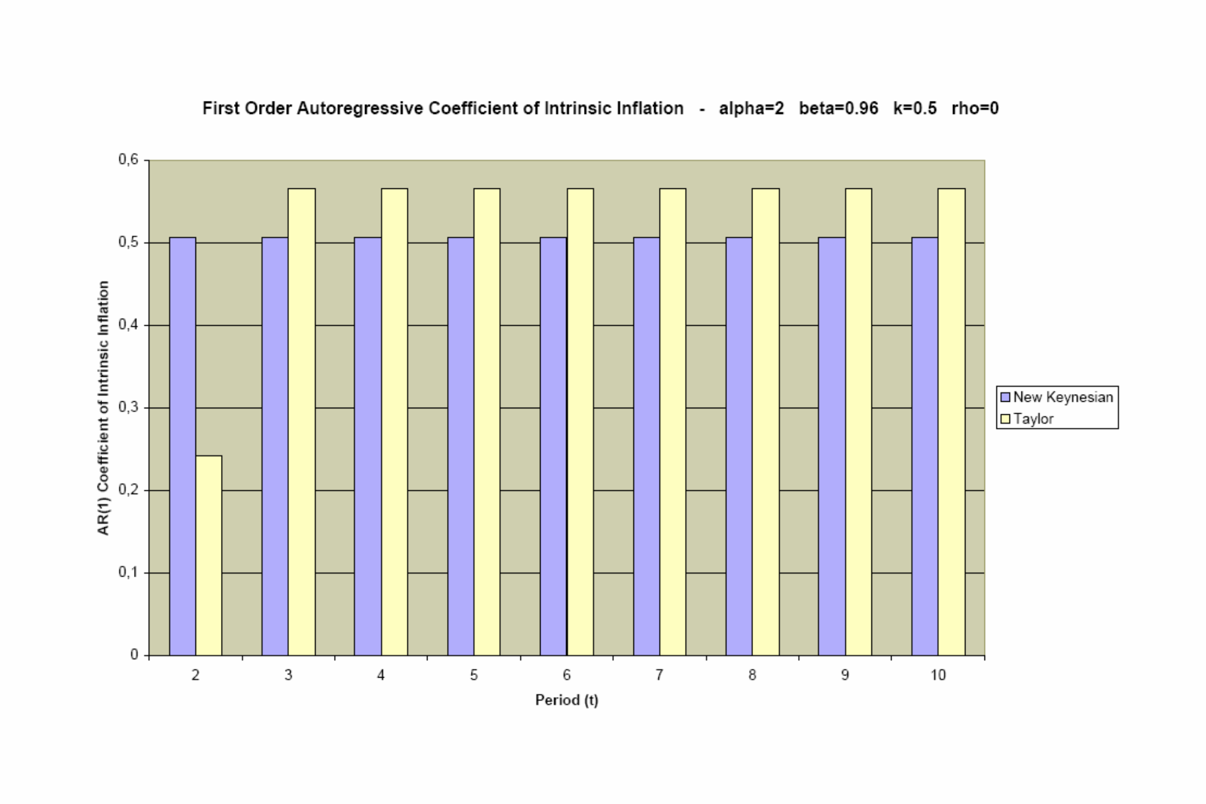
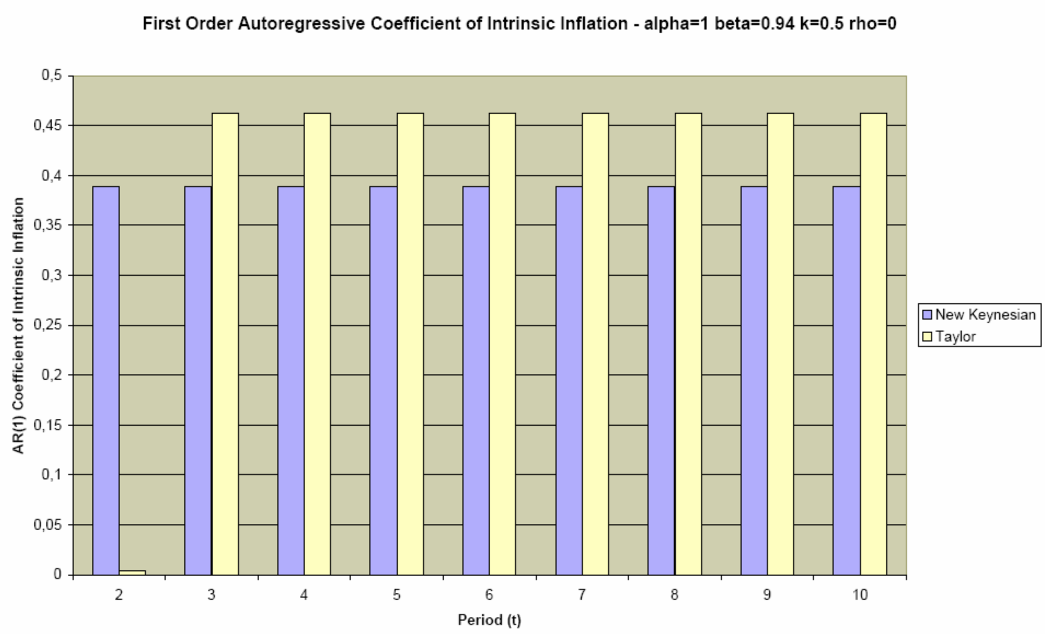
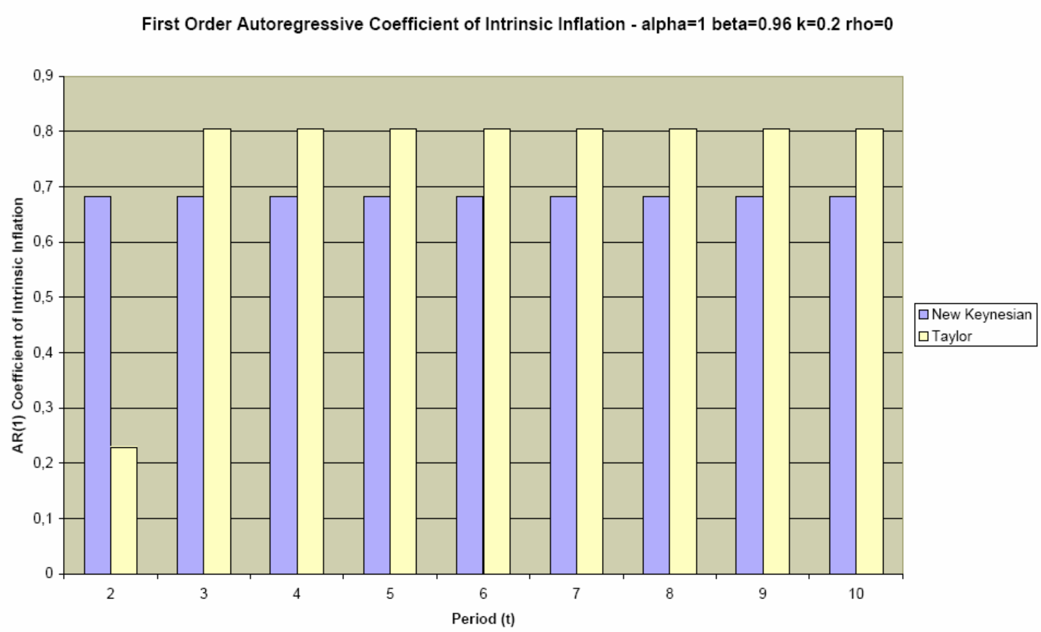


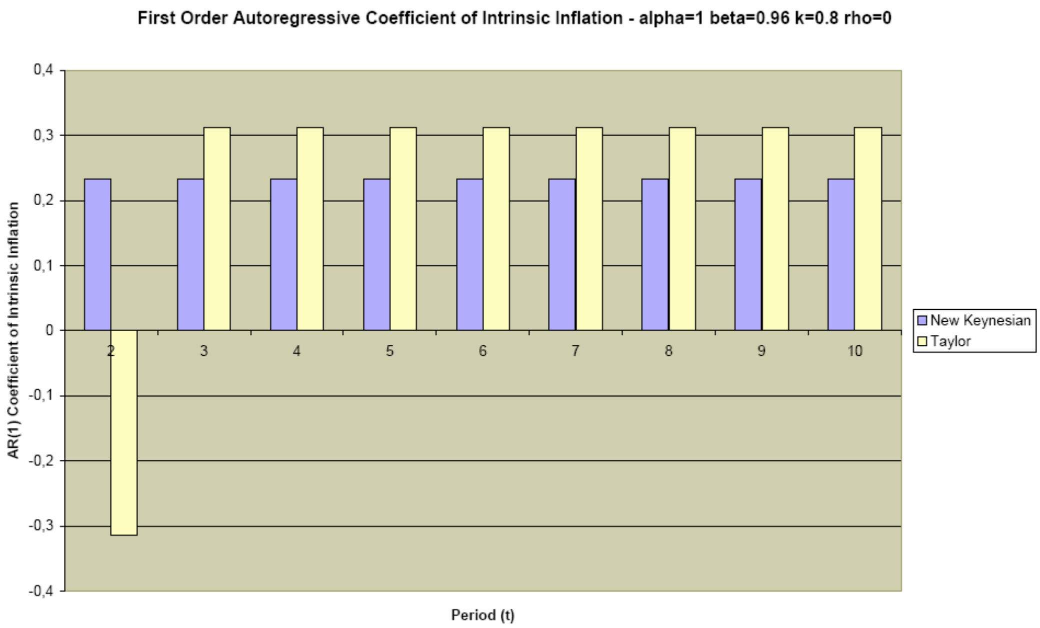
Figure 10: **Autoregression of Intrinsic Inflation - α=2, β=0,96, k=0,5, ρ=0.**



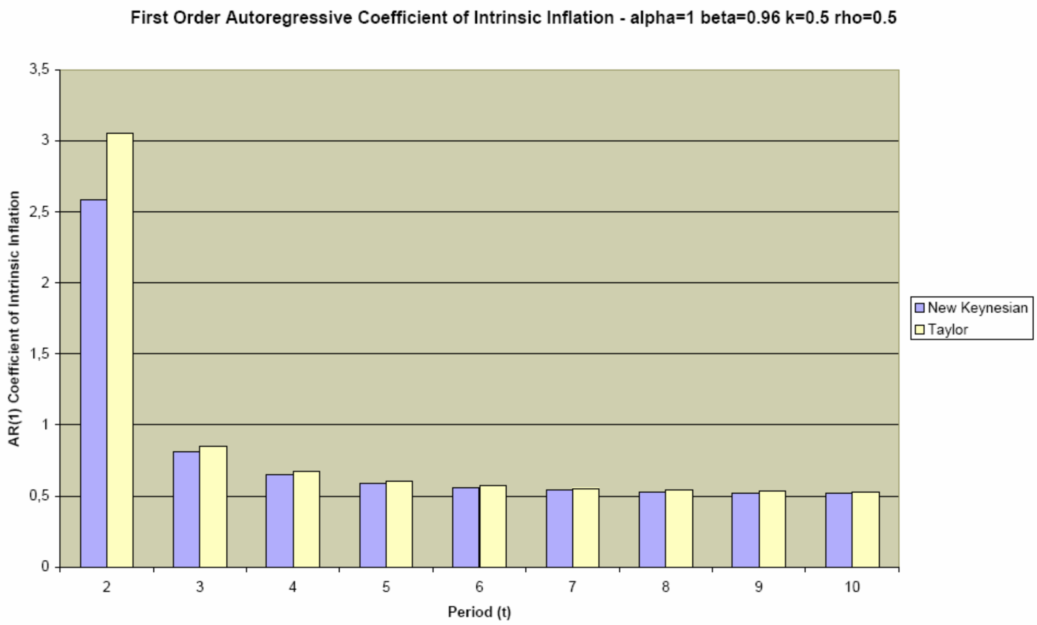
<u>Figure 11:</u> Autoregression of Intrinsic Inflation - α=1, β=0,94, k=0,5, ρ=0.



<u>Figure 12:</u> Autoregression of Intrinsic Inflation - α=1, β=0,96, k=0,2, ρ=0.



<u>Figure 13:</u> Autoregression of Intrinsic Inflation - α=1, β=0,96, k=0,8, ρ=0.



<u>Figure 14:</u> Autoregression of Intrinsic Inflation - α=1, β=0,96, k=0,5, ρ=0.5.

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