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Price Bargaining, the Persistence  
Puzzle, and Monetary Policy

by Dennis Wesselbaum

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We further discuss the role of those product market imperfections for monetary policy and find a trade-off between stabilizing intermediate or final good inflation. In addition, the Ramsey optimal monetary policy can be approximated reasonably well with a Taylor-type interest rate rule with weights on both inflation rates and output.

**Keywords:** Inflation and Output Persistence, Monetary Policy, Price Bargaining.

**JEL classification:** E31, E52, L10.

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# Price Bargaining, the Persistence Puzzle, and Monetary Policy\*

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June 13, 2010

## Abstract

In the recent New Keynesian literature a standard assumption is that the price for which an intermediate good is sold to the final good firm is equal to the marginal costs of the intermediate good firm. However, there is empirical evidence that this need not to hold. This paper introduces price bargaining into an otherwise standard New Keynesian DSGE model and shows that this model performs reasonably well in replicating the observed persistence values. We further discuss the role of those product market imperfections for monetary policy and find a trade-off between stabilizing intermediate or final good inflation. In addition, the Ramsey optimal monetary policy can be approximated reasonably well with a Taylor-type interest rate rule with weights on both inflation rates and output.

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# 1. Introduction

It is common knowledge amongst macroeconomists that standard New Keynesian models fail to explain the persistence of output and inflation in response to a monetary shock observed in the data, as e.g. shown by Chari et al. (2000), Mankiw (2000), or Huang and Liu (2002). To create a sufficient level of inflation and output persistence various authors added labor market frictions to the baseline model, e.g. Krause and Lubik (2007) or Lechthaler et al. (2008). However, the literature could not convincingly solve the persistence problem and therefore, we need to seek for new ideas to confront this sustaining challenge. Therefore, this paper presents an approach that is considerably different to present proposals. Within a segmented production sector we introduce price bargaining between the intermediate good firm and the final good firm. So far, bargaining is often used to solve the Diamond Paradox present in search models and is therefore considered to be the benchmark case to determine equilibrium wages in labor market models.

In the economy however, we observe the fact that within price setting decisions there is a considerable weight on the relative strength of the involved parties. Kleshchelski and Vincent (2007) introduce switching costs which give rise to long-term relationships between customer and producer. We further see considerations of the degree of dependency and the sensitivity of the purchaser. This leads to the need to model the price setting process by a bargaining approach. To be more precise, the intermediate good firm is not able to change to a new customer without generating switching costs, since a long-term seller-customer relationship creates positive externalities that act as turnover costs. Analogously, the same consideration holds for the final good firm while choosing a seller. An empirical analysis that is related to this approach was performed by Beckert (2009), who analyzes how buyer power is enhanced by the buyer's ability to switch between suppliers, and is constrained by the supplier's outside option and capacity.<sup>1</sup> Coherently, these turnover costs create economic rents that are splitted in price bargaining. The market power or the dependency of a firm is reflected in the relative bargaining strength and hence this price bargaining approach can not be considered to be an additional type of price rigidity, since prices are allowed to vary fully flexible.

Close to our paper is the work by Mathä and Pierrard (2009). They assume that product market imperfections are caused by search and matching frictions between buyers and sellers. However, we know from the labor market search and matching literature

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<sup>1</sup>In addition, - while the literature on buyer power is rather sparse - Inderst and Mazzarotto (2006) survey the recent efforts along this line.

that the matching function may not be invariant with respect to labor market policies and macroeconomic shocks as shown by Brown et al. (2009). As a consequence, the matching function may be subject to the Lucas critique. Furthermore, from the search and matching approach it is not clear how "unemployed" firms survive and why they do not exit the market.<sup>2</sup>

In the following, we introduce a New Keynesian model with four agents, households, two firms, and a monetary policy authority. The labor market is assumed to be neoclassical and monetary policy follows a standard Taylor rule. In this simple framework we are able to show humped-shaped IRFs and we obtain persistence values for output and inflation that fit the empirical estimates for the United States. In addition, we show that the monetary authority faces a trade-off in stabilizing either intermediate good or final good inflation. Furthermore, we show that a Taylor-type interest rule with weights on the two inflation rates and output is close to the Ramsey optimal policy.

The paper proceeds as follows. In Section 2 we derive the model and determine the optimality condition for the bargaining problem, Section 3 discusses three type of shocks, while Section 4 discusses the implications for monetary policy. Section 5 concludes.

## 2. The Model

The set up of the model is rather standard, i.e. we assume a representative household that supplies labor and purchases the final product produced by the final good firm. The production sector reveals a dual structure, with a finite number of intermediate good firms (IGF, henceforth) and a finite number of final good firms (FGF, henceforth). In the first stage, the IGF produces the intermediate good that is sold to the FGF for a bargained price. In the second stage, the FGF transforms the intermediate good into a final good that is finally sold to the household. The model is closed by the assumption that monetary policy follows a Taylor-rule.

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<sup>2</sup>In the labor market model, unemployed workers receive unemployment benefits such that there is no incentive to go out-of-the-labor-force.

## 2.1. Consumer Preferences

We assume a discrete-time economy with an infinite living representative household who seeks to maximize its utility given by

$$U_t = E_t \sum_{t=0}^{\infty} \beta^t \left[ \frac{C_t^{1-\sigma}}{1-\sigma} \right], \quad (1)$$

where  $\sigma > 0$  is the intertemporal elasticity of substitution of consumption and  $0 < \beta < 1$  is the intertemporal discount factor.<sup>3</sup> The household consists of a continuum of members, inelastically supplying one unit of labor and being represented by the unit interval. Household's demand is given by

$$C_{it} = \left( \frac{P_{it}}{P_t} \right)^{-\epsilon} C_t, \quad (2)$$

where  $P_t = \int_0^1 \left[ P_{it}^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}$  is the price index and  $C_t = \int_0^1 \left[ C_{it}^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}$  is the Dixit-Stiglitz aggregator. The demand function is faced by the monopolistically competitive final good firm while setting the price of its differentiated product  $i$ .

Furthermore, the household maximizes its utility subject to the intertemporal budget constraint

$$C_t + \frac{B_t}{P_t} \leq W_t + b(1 - N_t) + \Pi_t + T_t + R_{t-1} \frac{B_{t-1}}{P_t}. \quad (3)$$

Where  $b$  is the non-state-contingent parameter governing the opportunity cost from employment. In addition, household members insure each other against income fluctuations and have free and unlimited access to complete markets for state-contingent claims to avoid the problem of heterogeneity, i.e. we assume consumption pooling.<sup>4</sup>  $\Pi_t$  are profits from the intermediate and the final good firms being distributed to the household and  $T_t = \tau_t^R - \tau_t^{lt}$  is the difference of receiving transfers from the government  $\tau_t^R$  and paying lump sum taxes  $\tau_t^{lt}$ .  $R_t$  is the gross interest rate that satisfies  $R_{t-1} = 1 + i_{t-1}$ , where  $i_t$  is the nominal interest rate. The household takes the set of stochastic processes  $\{P_t, W_t, R_t\}_{t=0}^{\infty}$  as given, while choosing the values of  $\{C_t, B_t\}_{t=0}^{\infty}$ . Maximizing (1)

<sup>3</sup>Here, we follow Hansen (1985) by setting up an indivisible labor model.

<sup>4</sup>See Poilly and Sahuc (2008).

subject to (3) yields the standard Euler equation for which the No-Ponzi condition holds

$$C_t^{-\sigma} = \beta R_t E_t \left[ \frac{P_t}{P_{t+1}} C_{t+1}^{-\sigma} \right]. \quad (4)$$

## 2.2. The Segmented Production Sector

In the first stage of the production process, the IGF acts on a perfectly competitive market, in the sense that there are no nominal rigidities or frictions in the labor market or the financial sector. The relation between the two representative firms along the production process is characterized by switching costs. This assumption implies that there is a surplus that will be splitted between the two firms and is therefore the only "friction" that matters for the IGF (and, of course, the FGF).

The IGF then uses the following technology to produce output

$$Y_t^i = \mathcal{A}_t N_t^\alpha, \quad (5)$$

where  $\alpha > 0$  and  $\mathcal{A}_t$  is an AR(1) technological process. Since labor,  $N_t$ , is the only input, and therefore the only cost causing factor, the maximization problem of the IGF is given by

$$\Pi_t^i = E_t \sum_{t=0}^{\infty} \beta^t (P_t^i Y_t^i - W_t N_t), \quad (6)$$

where  $P_t^i$  is the price for which the intermediate good is sold to the final goods firm and  $W_t$  is the wage paid to each worker. This problem is subject to the production function (5) and the bargaining outcome for the optimal intermediate goods price, to be determined later.

Labor demand in the environment of a neoclassical labor market is given by

$$N_t = \left( \frac{W_t}{\alpha \mathcal{A}_t P_t^i} \right)^{\frac{1}{\alpha-1}}, \quad (7)$$

while the wage adjusts to clear the market and hence we obtain the standard neoclassical equation

$$W_t = \alpha \mathcal{A}_t N_t^{\alpha-1}. \quad (8)$$



In the second stage of the production process, the FGF acts on a monopolistically competitive market, produces the final good and sells this product to the household. For this purpose, the firm purchases  $Y_t^i$  units of the intermediate good and transforms it into the final good by using the linear production function

$$Y_t^f = Y_t^i. \quad (9)$$

The FGF only arises costs from purchasing the intermediate good and hence the total costs are given by

$$TC_t^f = P_t^i Y_t^i. \quad (10)$$

The FGF maximizes the discounted expected sum of profits given by

$$\Pi_t^f = E_t \sum_{t=0}^{\infty} \beta^t \left[ \frac{P_{it}}{P_t} Y_t^f - P_t^i Y_t^i - \frac{\psi}{2} \left( \frac{P_t}{P_{t-1}} - \pi \right)^2 Y_t^f \right], \quad (11)$$

where the latter term gives the quadratic Rotemberg (1982) adjustment costs and  $\psi > 0$  drives the size of those costs. Then, the firm maximizes eq. (11) subject to the sequence of demand equations (recall (2)) and the production function

$$Y_{it}^f = \left( \frac{P_{it}}{P_t} \right)^{-\epsilon} Y_t^f, \quad (12)$$

$$Y_t^f = Y_t^i, \quad (13)$$

since in equilibrium the market clearing condition holds.<sup>5</sup> The last equation is simultaneously the demand for the intermediate good, due to the assumption of a linear production function (consider eq. (9)).

The first-order condition for this problem with respect to the optimal retail price  $P_t^i$  is given by

$$1 - \psi(\pi_t - \pi)\pi_t + E_t \beta_{t+1} \left[ \psi(\pi_{t+1} - \pi)\pi_{t+1} \frac{Y_{t+1}^f}{Y_t^f} \right] = \epsilon(1 - P_t^i). \quad (14)$$

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<sup>5</sup>Hence,  $C_{it} = Y_{it}^f$  and  $C_t = Y_t^f$ .

Assuming zero net inflation in steady state and log-linearizing this equation gives the New Keynesian Phillips curve, i.e.

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa \hat{P}_t^i, \quad (15)$$

where

$$\kappa = \frac{\epsilon - 1}{\psi}. \quad (16)$$

In the next section, we derive the optimal price for the intermediate good.

### 2.3. Price Bargaining

The bargaining between the IGF and the FGF is assumed to follow a standard Nash bargaining problem.<sup>6</sup> Although later on we will consider the case of asymmetric bargaining ( $\eta \neq 0.5$ ) we neglect the distortions arising from the fact that in this asymmetric case the IIA assumption is violated, since the solution of the bargaining process potentially is an agreement between unrealistic, i.e. irrelevant, alternatives. However, the decisive factor in the bargaining is the relative bargaining strength of the FGF, i.e.  $0 \leq \eta \leq 1$ . The Nash bargaining product is then given by

$$\Lambda = (\Pi_t^f - \mathcal{S})^\eta (\Pi_t^i - \mathcal{S})^{1-\eta}, \quad (17)$$

and contains the two expected profits, while the two fall back positions are the switching costs,  $\mathcal{S}$ , i.e. if there is no agreement on the price, there will be no profits generated and the relationship breaks and both firms need to switch to a new seller/buyer.<sup>7</sup>

Inserting equations (6) and (11) yields

$$\Lambda = \left[ (P_t - P_t^i) Y_t^i - \frac{\psi}{2} \left( \frac{P_t}{P_{t-1}} - \pi \right)^2 Y_t^i - \mathcal{S} \right]^\eta [P_t^i Y_t^i - W_t N_t - \mathcal{S}]^{1-\eta}, \quad (18)$$

where  $P_t^i$  is the intermediate good price that is currently subject to the bargaining. Maximizing this function with respect to the intermediate goods price and applying the

<sup>6</sup>See Becker (2009) for a similar approach.

<sup>7</sup>Switching Costs are not explicitly included into the maximization problem of the firm, but implicitly through the intermediate good price. This follows from our timing assumption, that switching costs would have to be paid before maximization takes place.

necessary condition,  $\frac{\partial \Lambda}{\partial P_t^i} = 0$ , after some algebra yields

$$P_t^i = (1 - \eta)P_t + \eta \frac{W_t N_t}{Y_t^i} - (1 - \eta) \frac{\psi}{2} \left( \frac{P_t}{P_{t-1}} - \pi \right)^2 - (1 - 2\eta) \frac{\mathcal{S}}{Y_t^i}. \quad (19)$$

This equation reflects the factors considered by the two firms in the bargaining, being (i) the retail price of the FGF, (ii) the unit costs of the IGF, (iii) the Rotemberg (1982) adjustment costs per unit, and (iv) the per unit switching costs.

Let us consider the two extreme cases,  $\eta = 0$ , and,  $\eta = 1$ , to understand the influence of the Rotemberg (1982) price adjustment costs. We obtain

$$P_t^i = \begin{cases} P_t - \frac{\psi}{2} \left( \frac{P_t}{P_{t-1}} - \pi \right)^2 - \frac{\mathcal{S}}{Y_t^i} & \text{if } \eta = 0, \\ (W_t N_t)/Y_t^i + \frac{\mathcal{S}}{Y_t^i} & \text{if } \eta = 1. \end{cases} \quad (20)$$

In the first case, in which the final good firm has no significant bargaining power, the price will be equal to the retail price minus the adjustment costs of the final good firm. Hence, this equation corresponds to the Nash response function of the FGF, i.e. the optimal retail price with the new input price. Simultaneously, this condition ensures non-negativity of FGF profits (consider eq. (11)).

In the latter case, the FGF has absolute bargaining power which leads the price to cover the unit costs of the IGF. It will not allow for lower prices, as in this case the fall back position - with zero profits - would be a binding restriction to the problem. Intuitively, the FGF does not need to adjust its retail price, since it is still optimal.

We can furthermore deduce that the higher the bargaining power of the FGF, the lower the share of the retail price distributed to the IGF and the more important the cost component of the IGF is. This is quite intuitive since, on the one hand, if the FGF has more power it will force the IGF to accept a lower price and, on the other hand, the stronger the FGF the more important is the cost-covering principle for the IGF. Such that they do not call for a high profit or markup instead they want the price to cover their unit costs. The switching costs deal as threats for the firm with the lower bargaining power to accept the demanded price.

## 2.4. Closing the Model

Monetary policy targets the short-term nominal interest rate by following a standard Taylor rule, given by

$$\left(\frac{i_t}{\bar{i}}\right) = \left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi_\pi} \left(\frac{Y_t^f}{\bar{Y}^f}\right)^{\phi_y} e^{\varphi_t}, \quad (21)$$

where  $\phi_\pi > 0$  and  $\phi_y > 0$  are the respective weights and  $\varphi_t$  is the interest rate shock, that is AR(1), i.e.  $\varphi_t = \rho_i \varphi_{t-1} + \epsilon_t$ . As a final step, we define the aggregate income for the household given by

$$Y_t = W_t N_t. \quad (22)$$

The model is then log-linearized around its steady state and simulated using Dynare. For the given stochastic process  $\{\mathcal{A}_t, \varphi_t\}_{t=0}^\infty$  a determined equilibrium is a sequence of allocation and prices  $\left\{Y_t, P_t, P_t^i, W_t, N_t, i_t, R_t, \pi_t, \pi_t^{P^i}\right\}_{t=0}^\infty$ , which for given initial conditions satisfies equations (4),(7),(8),(15),(19),(21), the interest rate shock, the productivity shock and the definitions for the real interest rate, i.e.  $R_t = i_t - \pi_{t+1}$  and the two possible inflation rates, i.e.  $\pi_t = P_t - P_{t-1}$  as well as  $\pi_t^{P^i} = P_t^i - P_{t-1}^i$ . We calibrate the model on a quarterly basis for the U.S. and set parameter values according to stylized facts and the recent literature.

The intertemporal elasticity of substitution of consumption  $\sigma$  is set to 2, in line with Christoffel and Linzert (2005). The discount factor  $\beta = 0.99$ , is standard in the literature. This value corresponds to the average real rate of 4 % p.a. in the data. We set the employment rate to 90 %, such that the unemployment rate is 10 %.  $\eta$ , the bargaining power, will be subject to a robustness check. In the baseline calibration we assume symmetric bargaining and hence  $\eta = 0.5$ .  $\epsilon$ , governing the price elasticity of demand, is set to 11, as standard in the literature. The price adjustment parameter  $\psi$  is set to 105, such that Rotemberg (1982) and Calvo staggering are set equal. Steady state inflation is  $\pi = 1$ . The autocorrelation of the interest rate shock is  $\rho_i = 0.8$ , which is in line with empirical evidence as shown by Fève et al. (2007) and Lechthaler et al. (2008). The monetary authority sets  $\phi_y = 1.5$  and  $\phi_\pi = 0.5$ .

## 3. Discussion

### 3.1. Interest Rate Shock

Consider a one percent increase in the nominal interest rate. As a direct consequence from the optimization behavior of households, consumption is shifted to the future and hence output decreases (see Figure 1). Consistently, firms decrease labor demand and employment falls. Furthermore, inflation decreases since marginal costs (the intermediate goods price) decrease. The intermediate good price falls with the final good price, as profits decrease. Therefore, the final good firm is not willing to accept the pre-shock price and the bargaining yields a lower price for the intermediate good. Straightforward, and as the system converges back to its (old) steady state, the intermediate good price increases back to its pre-shock value. While inflation is stabilized quite quickly after the shock, the monetary authority focuses on increasing output back to its steady state value. Therefore, inflation overshoots and converges from above back to its steady state. Let us turn to the second moments of our simulation presented in Table 1. The value of autocorrelation of output (inflation) in the data for the U.S. is 0.87 (0.56). The simulation gives a value of 0.81 (0.54) for the autocorrelation - up to first order - for output (inflation). In addition, the value for the autocorrelation of the intermediate good inflation is not in line with the evidence. Also, the value for employment is only two thirds of its empirical value. We can conclude that the model is able to replicate the two important values reasonably well. However, it has to emphasized that the higher persistence just shows up with an autocorrelated shock. The model is not able to create endogenous persistence, as the main channel through which the effects are accelerated is the bargaining channel. To be more precise, the nominal rigidities in the second stage of the process spill-over through the bargaining (see eq. (19)).

### 3.2. Cost-Push Shock

As a next example, consider a one percent cost-push shock (a shock to the New Keynesian Phillips Curve, see Figure 2). In response to the shock, firms decrease employment and with employment, output falls. As the final good firm raises its price, inflation increases. The monetary authority reacts in increasing the nominal interest rate according to its Taylor rule. The intermediate good price falls in contrast to the final good price. The reason is that the price adjustment costs of the final good firm increase and that employment decreases (consider eq. (19)). The trade-off in stabilizing either output or

inflation is visible due to the overshooting of both variables. The autocorrelation values are 0.63 (data: 0.87) for output and 0.62 (data: 0.56) for inflation. In addition, the value for employment and the two prices fit their empirical counterparts. Furthermore, the model almost half of the autocorrelation of the intermediate good price inflation. It appears that the cost-push shocks seems to be important in the data.

### 3.3. Productivity Shock

Finally, we want to discuss a favorable one percent productivity shock (see Figure 3). The increased productivity leads firms to increase output by - simultaneously - lay-off more workers. As the shock also implies that final good prices fall, the intermediate good price also decreases. The monetary authority decreases the nominal interest rate in order to stabilize inflation. The second moments of our model economy show a mixed picture. The value for inflation is in line with the evidence. However, the values of output, employment and intermediate good prices are below their empirical counterparts. As we have seen before, it is difficult for the model to replicate the value of intermediate good price inflation. We can conclude that a combination of the discussed shocks generates the empirical values reasonably well.

## 4. Implications for Monetary Policy

So far, we have discussed the implications of price bargaining between intermediate good and final good producer. We have shown that a combination of shocks is able to replicate the empirically observed patterns of autocorrelations reasonably well. In particular, the interest rate shock seems to be important in the data. Now, we want to focus on the question whether the monetary authority should target the inflation measured by the final good price or by the intermediate good price.

At first, we want to consider the case that a benevolent Ramsey planner determines optimal monetary policy. Optimal monetary policy is the process  $\{R_t\}_{t=0}^{\infty}$  associated with the equilibrium that yields the highest level of utility to the representative household. The Ramsey planner chooses contingent plans for  $\{C_t\}_{t=0}^{\infty}$  so as to minimize the quadratic intertemporal loss function in period  $t$

$$\mathcal{L}_t = (1 - \beta)E_t \sum_{\tau=0}^{\infty} \beta^{\tau} \left[ \pi_{t+\tau}^2 + \pi_{t+\tau}^{P^i,2} + vY_{t+\tau}^2 \right], \quad (23)$$

where  $v$  is the relative weight on output stabilization. In the case that  $v = 0$ , we would have strict inflation targeting, while the more realistic case of  $v > 0$  corresponds to flexible inflation targeting.

Svensson (2002) has shown that, if the discount factor approaches unity and if a quarterly model is applied, the limit of the loss function (23) is simply the weighted sum of the unconditional variances of inflation and output, i.e.<sup>8</sup>

$$\lim_{\beta \rightarrow 1} \mathcal{L}_t = Var(\pi_t) + Var(\pi_t^{P^i}) + vVar(y_t). \quad (24)$$

Before we start to discuss our results, we want to briefly identify the distortions in our model economy. Average mark-up distortions are caused by the assumption of monopolistic competition. Dynamic mark-up distortions follow from the introduction of sticky prices. As before, we consider the optimal monetary policy response to an one percent favorable productivity shock. Figure 4 shows the response of selected variables. First, the increase in productivity induces an increase in output and a fall in employment. The Ramsey planner leads inflation to fall, since she is willing to take advantage of the entire productivity increase (see Faia (2009)). As a consequence, mark ups decrease and profits increase. Therefore, employment starts to converge back to its steady state. The overshooting of the inflation rate comes from the fact that the commitment policy of the Ramsey planner allows to anchor expectations about future variables. So, the Ramsey planner wants to increase inflation above its steady state for some time in order to allow a faster convergence back to its steady state.

For different degrees of the bargaining power of the final good firm, viz.  $\eta$ , we present the optimal monetary policy in Figure 5. We can infer that the higher the bargaining power of the FGF, the smaller is the output response. This carries over into a less strict decrease of employment for higher bargaining powers. Inflation decreases by a larger amount with increasing  $\eta$  and shows no longer an overshooting, instead it converges back from below to its steady state. In addition, the initial drop of intermediate good inflation is larger while the overshooting is larger and more persistent. The intuition for those patterns is the following. Starting from a low degree of bargaining power for the final good firm, the productivity shock leads output to increase and prices to fall. As the IGF has more power, it forces the FGF to accept higher prices (compare inflation rates for different values of  $\eta$  in Figure 5), i.e. a larger share of the surplus or profits is distributed to the IGF. As a consequence, the monetary authority has to lower interest

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<sup>8</sup>In addition, it has to hold that the unconditional mean of inflation equals the inflation target, i.e.  $E[\pi_t] = \pi^*$ .

rates by more to reach its stabilization goals, hence increasing the output response and creating an undershooting.

Table 2 presents the losses for the three considered parameter calibrations. We can infer that the symmetric case yields the smallest loss, while deviations from this point yield higher losses. As we have seen before, the monetary authority is able to stabilize either intermediate or final good inflation. If  $\eta = 1$ , i.e. if the FGF has the entire bargaining power, the volatility of the intermediate inflation is large, because in this case the intermediate price is entirely driven by wages, employment and output, while there are no dampening effects from final good prices (or the associated adjustment costs) leading to larger fluctuations.

In addition, we want to analyze five different interest rules of the following structure,

$$\left(\frac{i_t}{\bar{i}}\right) = \left(\frac{i_{t-1}}{\bar{i}}\right)^{\rho_S} \left[ \left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi_\pi} \left(\frac{\pi_t^{P^i}}{\bar{\pi}^{P^i}}\right)^{\phi_{\pi^{P^i}}} \left(\frac{Y_t^f}{\bar{Y}^f}\right)^{\phi_y} \right]^{1-\rho_S}, \quad (25)$$

where  $\phi_\pi \geq 0$ ,  $\phi_{\pi^{P^i}} \geq 0$ , and  $\phi_y > 0$  are the respective weights on inflation, intermediate good inflation, and output. In addition,  $\rho_S$  gives the degree of interest rate smoothing.

We define the set of parameters determining this rule such that

- Rule 1:  $\rho_S = 0$ ,  $\phi_\pi = 1.5$ ,  $\phi_{\pi^{P^i}} = 1.5$ , and  $\phi_y = 0.5$ ,
- Rule 2:  $\rho_S = 0$ ,  $\phi_\pi = 1.5$ ,  $\phi_{\pi^{P^i}} = 0$ , and  $\phi_y = 0.5$ ,
- Rule 3:  $\rho_S = 0$ ,  $\phi_\pi = 0$ ,  $\phi_{\pi^{P^i}} = 1.5$ , and  $\phi_y = 0.5$ ,
- Rule 4:  $\rho_S = 0.9$ ,  $\phi_\pi = 1.5$ ,  $\phi_{\pi^{P^i}} = 0$ , and  $\phi_y = 0.5$ ,
- Rule 5:  $\rho_S = 0.9$ ,  $\phi_\pi = 0$ ,  $\phi_{\pi^{P^i}} = 1.5$ , and  $\phi_y = 0.5$ .

These rules are compared in Figure 6 and Table 3 for an one percent favorable productivity shock, since this shock is known to be the main driving force of business cycles (see Faia (2009)). From this comparison we can draw the conclusion that the Taylor-type interest rule "classical" parameter calibration and weight on intermediate good inflation (see Rule 1) yields the smallest loss. Following this rule, the monetary authority is mainly concerned with stabilizing the two inflation rates and is successful in doing so. It decreases the interest rate by the largest amount and achieves its stabilization goal while creating a quite large drop in employment. All other rules allow for larger variation in the inflation rate, while the variance of the intermediate good inflation is quite large for the best rule. However, one would expect that the monetary authority



can simultaneously stabilize the two inflation rates. However, and as visible e.g. from Rule 1, stabilizing inflation comes along with larger deviations of employment which has an impact on the intermediate good price (and inflation). Therefore, the monetary authority faces a trade-off between stabilizing either the final good inflation, or the intermediate good inflation (see also Table 2). Taking output into consideration is not changing the picture. The inflation rates determine the order of the rules in terms of losses. It should be emphasized however, that Rule 5 - with smoothing and weight on intermediate good inflation - generates the smallest value of output fluctuation. To sum up, Rule 1 yields the smallest loss and is very similar to the optimal ramsey policy. If we compare the losses from the optimal policy and Rule 1, we find that the optimal policy creates a loss of 0.07, while the rule creates a loss of 0.0715. We can deduce that Rule 1 is a fairly well approximation of the optimal policy.

## 5. Conclusion

In the recent New Keynesian literature a standard assumption is that the price for which an intermediate good is sold to the final good firm is equal to the marginal costs of the intermediate good firm. However, there is empirical evidence that this need not to hold. Along this line, we introduce price bargaining into an otherwise standard New Keynesian DSGE model and show that this model performs reasonably well in replicating the observed autocorrelations. The purpose of this paper is to stress the role that product market imperfections, here switching costs between different product stages, have for business cycle fluctuations. Consistently, we understand this paper as a starting point for future research on this point.

The discussed improvement comes from the fact that nominal rigidities in the final good sector are transmitted via the bargaining to the intermediate good sector creating additional persistence. Having laid out the underlying mechanism, we also address the role of this additional feature for the design and implementation of monetary policy. We find that the monetary authority faces a trade-off between stabilizing either intermediate good or final good inflation. Furthermore, we find that a Taylor-type interest rate rule with weight on both inflation rates and output is close to the Ramsey optimal monetary policy.

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## B. The Bargaining Problem

The Nash bargaining product is given by

$$\Lambda = (\Pi_t^f)^\eta (\Pi_t^i)^{1-\eta}, \quad (26)$$

which can be written - using the profit equations - as

$$\Lambda = \left( (P_t - P_t^i) Y_t^i - \frac{\psi}{2} \left( \frac{P_t}{P_{t-1}} - \pi \right)^2 Y_t^i - \mathcal{S} \right)^\eta (P_t^i Y_t^i - W_t N_t - \mathcal{S})^{1-\eta}. \quad (27)$$

The FOC is given by

$$\frac{\partial \Lambda}{\partial P_t^i} = 0 = \eta \left( (P_t - P_t^i) Y_t^i - \frac{\psi}{2} \left( \frac{P_t}{P_{t-1}} - \pi \right)^2 Y_t^i - \mathcal{S} \right)^{\eta-1} (P_t^i Y_t^i - W_t N_t - \mathcal{S})^{1-\eta} (-Y_t^i) \quad (28)$$

$$+ (1-\eta) Y_t^i \left( (P_t - P_t^i) Y_t^i - \frac{\psi}{2} \left( \frac{P_t}{P_{t-1}} - \pi \right)^2 Y_t^i - \mathcal{S} \right)^\eta (P_t^i Y_t^i - W_t N_t - \mathcal{S})^{-\eta}. \quad (29)$$

Rearranging gives

$$\eta P_t^i Y_t^i - W_t N_t \eta - \eta \mathcal{S} = (1-\eta) (P_t - P_t^i) Y_t^i - \frac{\psi}{2} (1-\eta) \left( \frac{P_t}{P_{t-1}} - \pi \right)^2 Y_t^i - (1-\eta) \mathcal{S}. \quad (30)$$

Furthermore, dividing by  $Y_t^i$  and solving for  $P_t^i$ , gives

$$P_t^i = (1-\eta) P_t + \eta \frac{W_t N_t}{Y_t^i} - (1-\eta) \frac{\psi}{2} \left( \frac{P_t}{P_{t-1}} - \pi \right)^2 - (1-2\eta) \frac{\mathcal{S}}{Y_t^i}. \quad (31)$$

## C. The Linearized Equation System

Assume that  $\pi = 1$  and let variables without time index denote steady state values.

4 Using market clearing, i.e. ( $C = Y$ ),

$$\hat{Y}_t = \hat{Y}_{t+1} - \frac{1}{\sigma} \hat{R}_t, \quad (32)$$

7

$$\hat{N}_t = \frac{1}{\alpha - 1} \left( \frac{W}{\alpha P^i} \right)^{\frac{1}{\alpha-1}} (\hat{W}_t - \hat{P}_t^i - \hat{A}_t), \quad (33)$$

8

$$W\hat{W}_t = \alpha N^{\alpha-1} ((\alpha - 1)\hat{N}_t + \hat{A}_t), \quad (34)$$

15

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa \hat{P}_t^i, \quad (35)$$

19

$$\hat{P}_t^i = \frac{(1 - \eta)P}{(P^i)^2} \hat{P}_t + (\hat{W} + \hat{N} - \hat{Y}) \left( \frac{\eta W N}{Y (P^i)^2} \right), \quad (36)$$

22

$$\hat{i} = \phi_\pi \hat{\pi}_t + \phi_y \hat{Y}_t^f + \varphi_t, \quad (37)$$

Interest Rate Shock

$$\varphi_t = \rho_i \varphi_{t-1} + \epsilon, \quad (38)$$

Productivity Shock

$$\mathcal{A}_t = \rho_{\mathcal{A}} \mathcal{A}_{t-1} + \epsilon, \quad (39)$$

Real Interest Rate

$$\hat{R}_t = \hat{i}_t - \hat{\pi}_{t+1}, \quad (40)$$

Inflation

$$\hat{\pi}_t = \hat{P}_t - \hat{P}_{t-1}. \quad (41)$$

Inflation, Intermediate Price

$$\hat{\pi}_t^{P^i} = \hat{P}_t^{P^i} - \hat{P}_{t-1}^{P^i}. \quad (42)$$

# D. Tables and Figures

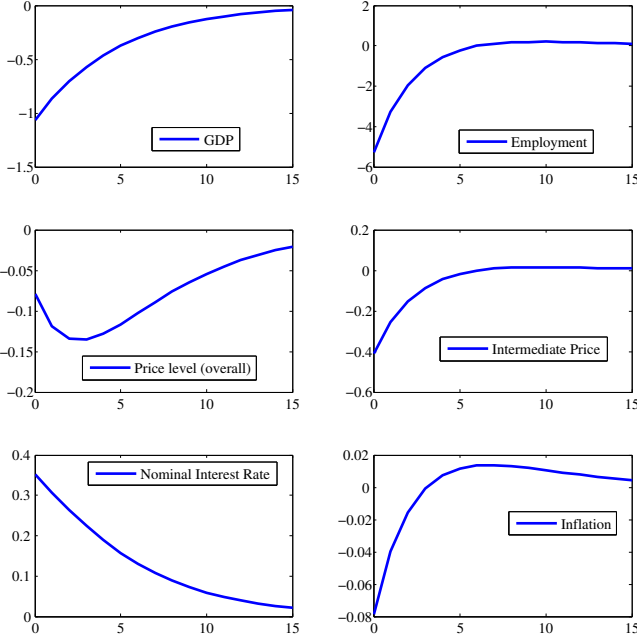


Figure 1: Positive Interest Rate Shock.

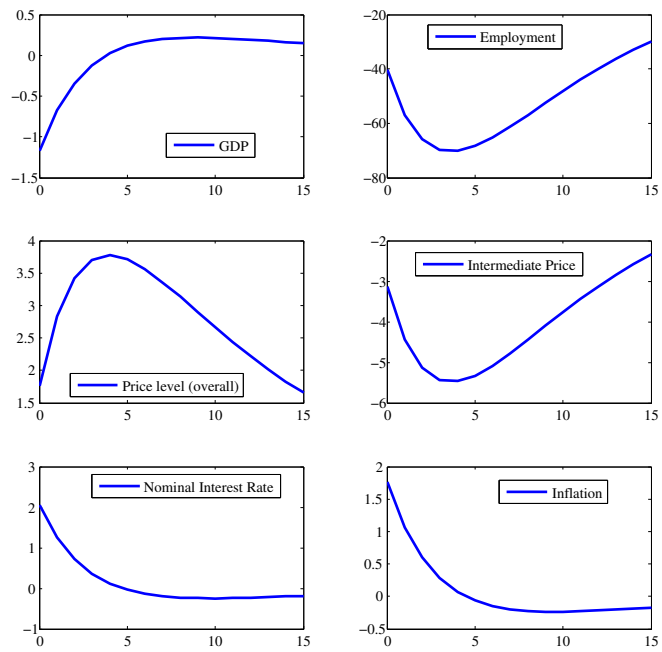


Figure 2: Cost-Push Shock.



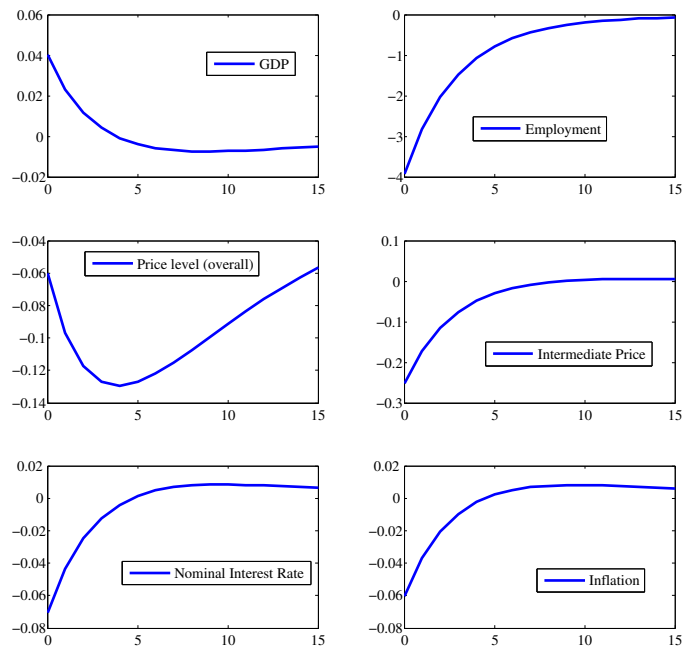


Figure 3: Positive Productivity Shock.

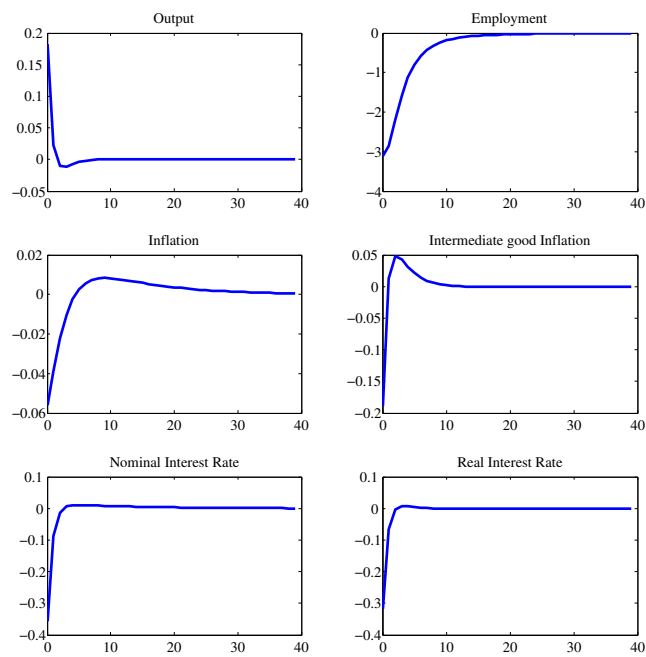


Figure 4: Ramsey Monetary Policy.

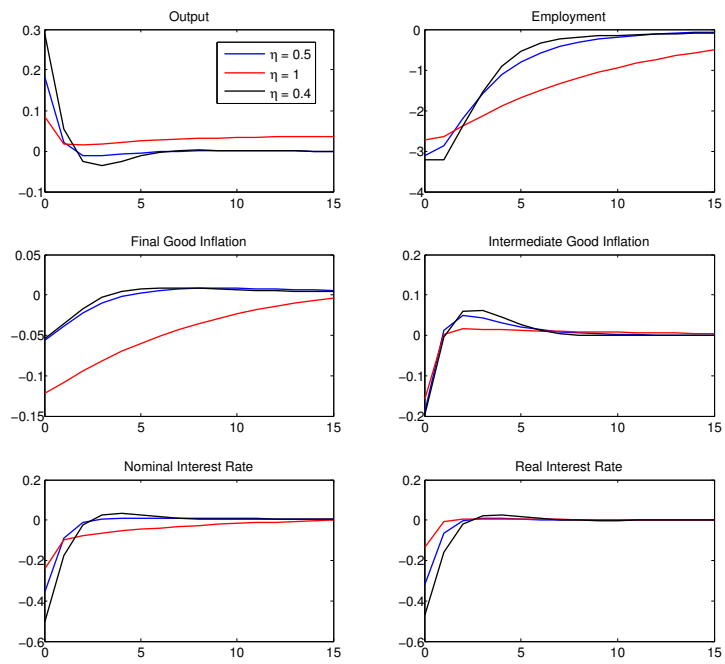


Figure 5: Optimal Monetary Policy for Different Bargaining Weights.

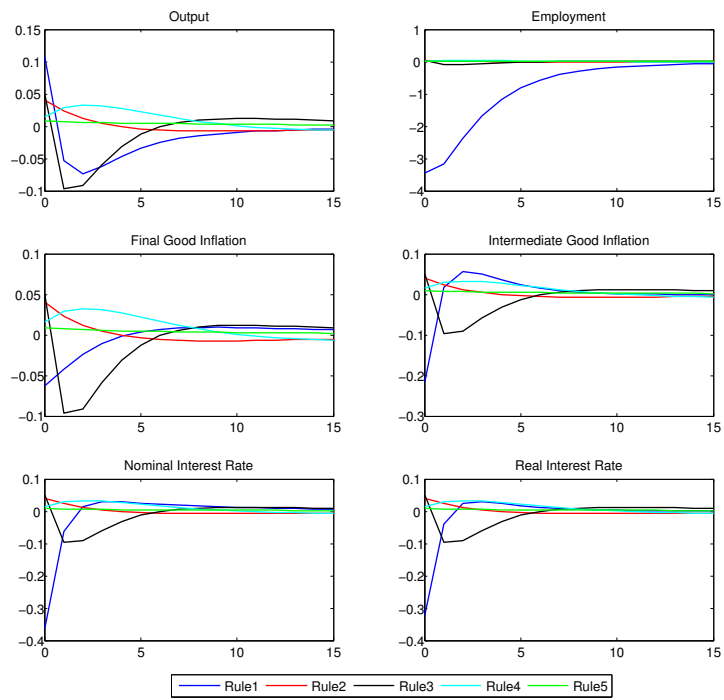


Figure 6: Response of the Model to Different Interest Rate Rules.

Table 1: Autocorrelations.

	$Y$	$N$	$\pi$	$\pi^{P^i}$	$P$	$P^i$
Data	0.87	0.94	0.56	0.77	0.97	0.97
Productivity	0.63	0.72	0.62	-0.15	0.98	0.67
Interest-Rate	0.81	0.61	0.54	-0.17	0.96	0.61
Cost-Push	0.63	0.98	0.62	0.48	0.98	0.98
Joined	0.74	0.98	0.62	0.47	0.98	0.98

Notes: Simulation values are theoretical moments. Data values for output and inflation are taken from Krause and Lubik (2007). Values for the remaining variables are computed by taking time series for the period 1964:1 to 2002:3 (as in Krause and Lubik (2007)), taking logs and HP-filtering ( $\lambda = 10^5$ ) those series. Time series are obtained from the BLS. For the final good price we take the CPI data for all U.S. items, while for the intermediate good price we take the PPI for intermediate goods. Employment is total private employment.

Table 2: Losses under Optimal Monetary Policy for Different Bargaining Weights.

Case	$Var(\pi_t)$	$Var(\pi_t^{P^i})$	$vVar(y_t)$	$\mathcal{L}$
$\eta = 0.5$	0.0072	0.0550	0.0286	0.07
$\eta = 1$	0.0062	0.0765	0.0029	0.1193
$\eta = 0.4$	0.0074	0.0690	0.0261	0.0989

Notes: Theoretical Moments.  $v = 0.5$ .

Table 3: Losses under Different Rules.

Rule	$Y$	$\pi$	$\pi^{P^i}$	$Var(\pi_t)$	$Var(\pi_t^{P^i})$	$vVar(y_t)$	$\mathcal{L}$
Rule 1	0.5	1.5	1.5	0.0072	0.0550	0.0286	0.0715
Rule 2	0.5	1.5	0	0.0062	0.0765	0.0029	0.0842
Rule 3	0.5	0	1.5	0.0074	0.0690	0.0261	0.0895
Rule 4	0.5	1.5	0	0.0058	0.0859	0.0054	0.0944
Rule 5	0.5	0	1.5	0.0063	0.0856	0.0004	0.0921

Notes: Theoretical Moments. Rules 4 and 5 also show smoothing.  $v = 0.5$ .