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by

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Firm-Specific Investment, Sticky Prices, and the Taylor Principle*

Tommy Sveen† Lutz Weinke‡

September 10, 2004

Abstract

According to the Taylor principle a central bank should adjust the nominal interest rate by more than one for one in response to changes in current inflation. Most of the existing literature supports the view that by following this simple recommendation a central bank can avoid being a source of unnecessary fluctuations in economic activity. The present paper shows that this conclusion is not robust with respect to the modelling of capital accumulation. We use our insights to discuss the desirability of alternative arrangements for the conduct of monetary policy.

Keywords: Sticky Prices, Investment, Monetary Policy.

JEL Classification: E22, E31

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1 Introduction

According to the Taylor principle a central bank should follow an active monetary policy, i.e. it should adjust the nominal interest rate by more than one for one in response to changes in current inflation. Simple interest rate rules consistent with that recommendation guarantee determinacy, i.e. local uniqueness of rational expectations equilibrium (REE), in many dynamic New-Keynesian (DNK) models.[1] Given its apparent robustness Clarida et al. (2000), and a large subsequent literature, use the Taylor principle to judge the conduct of monetary policy in practice.

In the present paper we reassess the usefulness of the Taylor principle. Our model features Calvo pricing, combined with firm-specific capital, i.e. we assume a convex capital adjustment cost at the firm level. This set of assumptions has been originally proposed in Woodford (2003, Ch. 5).[2] Surprisingly, we find that an active monetary policy is *not* a sufficient condition for determinacy. This is interesting because most of the existing literature supports the view that the Taylor principle is robust with respect to the modelling of capital accumulation. An exception is Dupor (2001). His result that a passive interest rate rule is required to guarantee determinacy appears, however, to be specific to the continuous time framework he employs. In a discrete-time model Galí et al. (2004) find that it is not endogenous capital *per se* that challenges the Taylor principle.[3]

How is it possible that we reach a different conclusion in the present paper? The answer is that the convenient and widely used rental market assumption is not

[1] See, e.g., Taylor (1999a) and Woodford (2001).

[2] Sveen and Weinke (2003, 2004a,b) explain the economic mechanism through which firm-specific capital affects inflation dynamics in the Calvo model. The latter has been obsured by a conceptual mistake in Woodford (2003, Ch. 5), as we note. Since we wrote and circulated our papers there have been other contributions that stress the fruitfulness of assuming firm-specific capital in a model with staggered price setting. See, e.g., Altig et al. (2004), Eichenbaum and Fisher (2004), and Woodford (2004).

[3] Lubik (2003) obtains a similar result. He finds that determinacy obtains under an active monetary policy, if conventional values are assigned to both the capital adjustment cost and the price stickiness parameter. His results are, however, extremely sensitive with respect to the choice of the capital adjustment cost parameter. Carlstrom and Fuerst (2003) find that forward-looking interest rate rules do generally not guarantee determinacy in a DNK model with capital accumulation. They do not challenge, however, the usefulness of the Taylor principle.

innocuous: it hides an indeterminacy problem. The intuition is as follows. Current investment increases current marginal cost, but it lowers marginal cost in the future. A central bank that follows the Taylor principle therefore tends to decrease future real interest rates in the aftermath of an investment boom. Hence, to the extent that investment is forward-looking, the expectation of such a boom could potentially become self-fulfilling. Whether this possibility materializes or not depends on the degree of price stickiness. The higher the price stickiness the more likely it is that the expectation of an investment boom is self-fulfilling, as we will discuss. The last aspect is crucial for the fact that the rental market assumption hides an indeterminacy problem. As we show in Sveen and Weinke (2004b) the difference between a specification with firm-specific capital and an alternative formulation with a rental market boils down to a difference in *effective* price stickiness:[4] price setters are relatively more reluctant to change their prices if the capital stock at the firm level is predetermined, i.e. for any given exogenous restriction on price adjustment there is less price stickiness, if a rental market for capital is assumed.[5] Assuming a rental market for capital is therefore not innocuous in a model with staggered price setting: the resulting price stickiness will generally be too low to make the indeterminacy issue appear to be relevant from a practical point of view.[6] This conclusion changes dramatically, if capital is assumed to be firm-specific. Indeed, in the present paper, we find that the Taylor principle is a poor guide for the conduct of monetary policy, once investment decisions are modelled at the firm level.

Moreover, we find that the conditions for determinacy are much more likely to be satisfied, if the central bank reacts *not* only to inflation but also to some measure

[4]The difference in implied price stickiness is therefore a useful metric: Sveen and Weinke (2004b) show that, for a standard calibration of the two models, one needs a Calvo parameter of about 0.9 in the rental market model in order to obtain the equilibrium dynamics resulting form a value of 0.75 in the model with firm-specific capital.

[5]The intuition is analog to the one that explains the difference in implied inflation dynamics resulting from assuming either constant returns to scale or decreasing returns to scale in a DNK model, along the lines discussed in Sbordone (2002) and Galí et al. (2001).

[6]Carlstrom and Fuerst (2003) note that 'if prices are extremely sticky' the Taylor principle is no longer sufficient for determinacy.

of economic activity. In other words, a central bank could potentially become a source of unnecessary economic fluctuations if it were to follow a rule according to which the nominal interest rate is set as a function of inflation only. The last result amends a recent finding by Schmitt-Grohé and Uribe (2004) with a caveat. They study the welfare properties of alternative interest rate rules across a rich variety of DNK models. Using a second order approximation they argue that responding to output is costly in welfare terms. However, based on our results we make the case for interest rate rules prescribing that the central bank should react to some measure of economic activity.[7]

The remainder of the paper is organized as follows: Section 2 outlines the model structure with firm-specific capital and explains how it changes under the alternative assumption of a rental market. Section 3 presents our results. We explain why the modeling of an investment decision at the firm level changes the determinacy properties of a DNK model so dramatically. Next it is shown that our findings are robust with respect to changes in the relevant structural parameters. Finally, we use our framework to discuss the desirability of alternative arrangements for the conduct of monetary policy. Section 4 concludes.

2 The Model

The economy is populated by households and firms. In what follows we reconsider the model with firm-specific capital outlined in Sveen and Weinke (2004a).[8] In the present paper we assume, however, that there is no aggregate uncertainty except for sunspots according to which economic agents agree on a particular equilibrium. A short description of the rental market case is left for the last paragraph.

[7] It should be noted that the analysis in Schmitt-Grohé and Uribe (2004) does not imply that it would be costly in welfare terms to respond to some output gap measure. However, it is unclear *a priori* how natural output should be defined in a model with endogenous capital, as discussed in Woodford (2003, Ch. 5).

[8] In Sveen and Weinke (2004a) we solve the model using an iterative procedure. In the present paper we follow Woodford (2004) and use the method of undetermined coefficients, which is computationally more efficient. See the Appendix for an outline of Woodford's solution.

2.1 Households

A representative household seeks to maximize expected discounted utility:[9]

$$E_t \sum_{k=0}^{\infty} \beta^k U\left(C_{t+k}, N_{t+k}\right), \tag{1}$$

where $U(\cdot)$ denotes the period utility function, β is a discount factor, N_t denotes hours worked in period t, and C_t is a Dixit-Stiglitz consumption aggregate as of that time. Specifically,

$$C_t = \left(\int_0^1 C_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}}. \tag{2}$$

where ε is the elasticity of substitution between different varieties of goods $C_t(i)$.

We assume the following period utility function:

$$U(C_t, N_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\phi}}{1+\phi}. \tag{3}$$

Parameter σ denotes the household's relative risk aversion, or equivalently, the inverse of the intertemporal elasticity of substitution, and parameter ϕ can be interpreted as the the inverse of the Frisch labor supply elasticity. Moreover, the household is assumed to supply labor in a competitive market.

The maximization is subject to the following sequence of budget constraints:

$$\int_0^1 P_t(i) C_t(i) di + E_t\left\{Q_{t,t+1} D_{t+1}\right\} \leq D_t + W_t N_t + T_t, \tag{4}$$

where W_t is the time t nominal wage, $Q_{t,t+1}$ is the stochastic discount factor for random nominal payments, D_{t+1} is the nominal payoff of the portfolio held at the end of period t, and T_t denotes profits resulting from ownership of firms.

For each variety of goods the consumption demand function reads:

$$C_t^d(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} C_t, \tag{5}$$

[9] It is assumed that households have access to complete financial markets.

where $P_t \equiv \left(\int_0^1 P_t(i)^{1-\varepsilon}\, di\right)^{\frac{1}{1-\varepsilon}}$ denotes the price index. It has the property that the minimum expenditure required to purchase a bundle of goods resulting in C_t units of the composite good is given by $P_t C_t$.

The remaining first order conditions associated with the household's problem are:

$$C_t^{\sigma} N_t^{\phi} = \frac{W_t}{P_t}, \tag{6}$$

$$\beta \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \left(\frac{P_t}{P_{t+1}}\right) = Q_{t,t+1}. \tag{7}$$

The first equation is the optimality condition for labor supply, and the second one is a standard intertemporal optimality condition. Finally, let us note that the time t gross nominal interest rate, R_t, is related to the stochastic discount factor by the equilibrium condition $R_t^{-1} = E_t\{Q_{t,t+1}\}$.

2.2 Firms

There is a continuum of monopolistically competitive firms, indexed on the unit interval. Each firm i has access to a Cobb-Douglas technology:

$$Y_t(i) = K_t(i)^{\alpha} N_t(i)^{1-\alpha}, \tag{8}$$

where α is the capital share in the production function, and $K_t(i)$ and $N_t(i)$ denote, respectively, firm i's capital stock and labor input used in its period t production denoted $Y_t(i)$.

We assume staggered price setting à la Calvo (1983), i.e. each firm faces a constant and exogenous probability, θ, of getting to reoptimize its price in any given period. This structure implies that firm i's nominal price, $P_t(i)$, is either the one that was posted the period before or the optimally chosen price $P_t^*(i)$.

Moreover, we follow Woodford (2003, Ch. 5) in assuming two restrictions on capital adjustment. First, the additional capital resulting from an investment decision becomes productive with a one period delay. Second, firms face a convex capital adjustment cost.[10] This is summarized in the following equation:

$$I_t(i) = I\left(\frac{K_{t+1}(i)}{K_t(i)}\right) K_t(i), \tag{9}$$

where $I_t(i)$ denotes the amount of the composite good[11] purchased by firm i at time t, and $K_t(i)$ denotes this firm's capital stock as of that period. Moreover, function $I(\cdot)$ is assumed to satisfy the following: $I(1) = \delta$, $I'(1) = 1$, and $I''(1) = \epsilon_\psi$. Parameter δ denotes the depreciation rate. Eichenbaum and Fisher (2004) interpret parameter ϵ_ψ as the elasticity of the investment to capital ratio with respect to Tobin's q, evaluated in steady state. Parameter ϵ_ψ is assumed to be strictly larger than zero and it measures the convex capital adjustment cost in a log-linear approximation to the equilibrium dynamics.

Cost minimization by firms and households implies that demand for each individual good i in period t can be written as follows:

$$Y_t^d(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t^d, \tag{10}$$

where Y_t^d denotes aggregate demand at time t, which is given by:

$$Y_t^d \equiv C_t + I_t,$$

and $I_t \equiv \int_0^1 I_t(i)\, di$ denotes aggregate investment demand.

Let us now consider a price setter's problem. Given its time t capital stock, $K_t(i)$, a price setting firm i chooses contingent plans for $\left\{P_{t+k}^*(i), K_{t+k+1}(i), N_{t+k}(i)\right\}_{k=0}^{\infty}$

[10] Sveen and Weinke (2003) consider a model with just the first restriction on a firm's capital accumulation, namely the one period delay.

[11] The elasticity of substitution, ε, is assumed to be the same as in the consumption aggregate.

in order to solve the following:

$$\max \sum_{k=0}^{\infty} E_t \left\{ Q_{t,t+k} \left[Y_{t+k}^d(i) P_{t+k}(i) - W_{t+k} N_{t+k}(i) - P_{t+k} I_{t+k}(i) \right] \right\} \tag{11}$$

s.t.

$$\begin{aligned}
Y_{t+k}^d(i) &= \left(\frac{P_{t+k}(i)}{P_{t+k}} \right)^{-\varepsilon} Y_{t+k}^d, \\
Y_{t+k}^d(i) &\leq N_{t+k}(i)^{1-\alpha} K_{t+k}(i)^{\alpha}, \\
I_{t+k}(i) &= I\left(\frac{K_{t+k+1}(i)}{K_{t+k}(i)} \right) K_{t+k}(i), \\
P_{t+k+1}(i) &= \begin{cases} P_{t+k+1}^*(i) & \text{with prob. } (1-\theta) \\ P_{t+k}(i) & \text{with prob. } \theta \end{cases}
\end{aligned}$$

A firm j that is restricted to change its price at time t solves the same problem, except for the fact that it takes $P_t(j)$ as given.

The first order condition for capital accumulation reads:

$$\frac{dI_t(i)}{dK_{t+1}(i)} P_t = E_t \left\{ Q_{t,t+1} \left[MS_{t+1}(i) - \frac{dI_{t+1}(i)}{dK_{t+1}(i)} P_{t+1} \right] \right\}, \tag{12}$$

where $MS_{t+1}(i)$ denotes the nominal reduction in firm i's labor cost associated with having one additional unit of capital in place in period $t+1$. The only non-standard feature of the last equation is that the marginal return to capital is *not* measured by the nominal marginal revenue product of capital, but instead by $MS_{t+1}(i)$. The reason is that firms are demand constrained, as discussed in Woodford (Ch. 5, 2003).

The following relationship holds true:

$$MS_t(i) = W_t \frac{MPK_t(i)}{MPL_t(i)}, \tag{13}$$

where $MPK_t(i)$ and $MPL_t(i)$ denote, respectively, the marginal product of capital and labor of firm i in period t.

The first order condition for price setting is given by:

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} Y_{t+k}^d (i) \left[P_t^* (i) - \mu MC_{t+k} (i) \right] \right\} = 0, \tag{14}$$

where $\mu \equiv \frac{\varepsilon}{\varepsilon - 1}$ denotes the frictionless mark-up over marginal costs, and $MC_t (i)$ denotes the nominal marginal cost of firm i in period t. The latter is given by:

$$MC_t (i) = \frac{W_t}{MPL_t (i)}. \tag{15}$$

Equation (14) reflects the forward-looking nature of price setting: firms take into account not only current but also future expected marginal costs in those states of the world where the chosen price is still posted.

2.3 Market Clearing

Clearing of the labor market:

$$N_t = \int_0^1 N_t (i) \, di. \tag{16}$$

Finally, market clearing for each variety i:

$$Y_t (i) = C_t^d (i) + I_t^d (i), \tag{17}$$

where $I_t^d (i)$ denotes time t investment demand for good i.

2.4 Some Linearized Equilibrium Conditions

We restrict attention to a linear approximation around a steady state with zero inflation. Throughout, a hat on a variable denotes the percent deviation of the original variable with respect to its steady state value.

2.4.1 Households

Solving the household's problem results in an Euler equation and in a labor supply equation. They read, respectively:

$$\widehat{C}_t = E_t\widehat{C}_{t+1} - \frac{1}{\sigma}\left(i_t - E_t\pi_{t+1} - \rho\right), \tag{18}$$

$$\widehat{\left(\frac{W_t}{P_t}\right)} = \phi\widehat{N}_t + \sigma\widehat{C}_t, \tag{19}$$

where $i_t \equiv \log R_t$ denotes the time t nominal interest rate, and $\pi_t \equiv \log\left(\frac{P_t}{P_{t-1}}\right)$ is time t inflation.

2.4.2 Firms

Law of Motion of Capital Aggregating and log-linearizing the first order condition for investment (12) and combining the resulting expression with the Euler equation (18), we obtain:

$$\begin{aligned}\widehat{K}_{t+1} = {} & \frac{1}{1+\beta}\widehat{K}_t + \frac{\beta}{(1+\beta)}E_t\widehat{K}_{t+2} \\ & + \frac{1-\beta(1-\delta)}{\epsilon_\psi(1+\beta)}E_t\widehat{ms}_{t+1} - \frac{1}{\epsilon_\psi(1+\beta)}\left(i_t - E_t\pi_{t+1} - \rho\right),\end{aligned} \tag{20}$$

where $K_t \equiv \int_0^1 K_t(i)\,di$ is the aggregate time t capital stock, and $ms_t \equiv \frac{1}{P_t}\int_0^1 MS_t(i)\,di$ denotes the average real marginal return to capital.

Inflation equation We follow Woodford (2004) and derive the inflation equation by employing the method of undetermined coefficients. He shows that it takes the following simple form:

$$\pi_t = \beta E_t\pi_{t+1} + \kappa\,\widehat{mc}_t, \tag{21}$$

where κ is a parameter which is computed numerically, and $mc_t \equiv \frac{1}{P_t}\int_0^1 MC_t(i)\,di$ is the average real marginal cost.

Production function Aggregating and log-linearizing the production functions of individual firms (8) results in:

$$\widehat{Y}_t = \alpha \widehat{K}_t + (1 - \alpha) \widehat{N}_t. \tag{22}$$

where Y_t is aggregate production. We have used the fact that we restrict attention to a linear approximation around a steady state with zero inflation.

Market clearing Aggregating and log-linearizing the goods market clearing condition for each variety (17), and invoking (8) and (10), we obtain:

$$\widehat{Y}_t = \frac{\rho + \delta (1 - \alpha)}{\rho + \delta} \widehat{C}_t + \frac{\alpha}{\rho + \delta} \left[\widehat{K}_{t+1} - (1 - \delta) \widehat{K}_t \right]. \tag{23}$$

The last equation reflects the assumption that the capital adjustment cost is assumed to be zero in steady state.

2.5 Rental Market

Now we assume that households accumulate the capital stock and rent it to firms.[12] This structure implies that each firm produces at the same marginal cost which is independent of the price posted by any individual firm. The associated inflation equation reads:

$$\pi_t = \beta E_t \pi_{t+1} + \lambda \widehat{mc}_t, \tag{24}$$

where $\lambda \equiv \frac{(1-\beta\theta)(1-\theta)}{\theta}$. It should be noted that the inflation equation is the only structural equation that is affected by the change in assumption regarding capital accumulation. This means that, given a specification of monetary policy, the equilibrium processes for the nominal interest rate, consumption, real wage, capital, output, hours, and inflation are determined by equations (18), (19), (20), (22), (23),

[12] The implied changes in the respective maximization problems of households and firms are obvious. See, e.g., Galí (2004) et al. for a derivation of the equilibrium conditions resulting from that set of assumptions.

and an inflation equation. The latter is given by equation (21) for the firm-specific capital model and by equation (24) for the rental market specification.[13] Next we explore what kinds of simple interest rate rules guarantee determinacy in the two New-Keynesian models under consideration, and why.

3 Results

3.1 Calibration

The period length is one quarter. Consistent with empirical estimates of the intertemporal elasticity of substitution given by Basu and Kimball (2003) we assume $\sigma = 2$. We set $\phi = 1$, implying a unit labor supply elasticity. We assign a standard value of 0.36 to the capital share in the production function, α. Setting $\beta = 0.99$ implies an average annual real return of about 4 percent. We choose $\varepsilon = 11$ implying a frictionless markup of 10 percent, which is in line with the empirical estimate in Galí et al. (2001). Finally, we set $\epsilon_\psi = 3$, as proposed by Woodford (2003, Ch. 5).

3.2 A Simple Interest Rate Rule

Our starting point is a simple interest rate rule according to which the nominal interest rate is set as a function of current inflation:

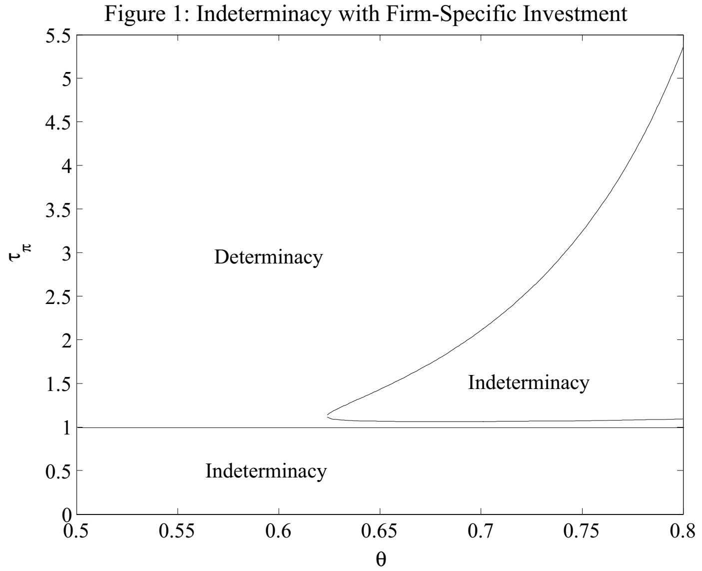
$$i_t = \rho + \tau_\pi \pi_t. \tag{25}$$

We ask what combinations of values for the inflation response coefficient, τ_π, and the price stickiness parameter, θ, result in a determinate equilibrium. The result is shown in Figure 1 for the model with firm-specific capital: a large range of parameter values that meet the Taylor principle are inconsistent with determinacy. In

[13] To solve the dynamic stochastic system of equations we use Dynare (http://www.cepremap.cnrs.fr/dynare/). Thanks to Larry Christiano for providing us with Matlab code which we have used in the computation of κ.

particular, for reasonable calibrations of the price stickiness parameter we obtain an apparently counterintuitive result: an inflation response coefficient, τ_π, strictly larger than one is necessary but *not* sufficient for determinacy. For response coefficients in that range REE is determinate only if the central bank adjusts the nominal interest rate either very gently or very aggressively.[14] Next we develop the intuition behind these results.

Figure 1: Indeterminacy with Firm-Specific Investment



Let us start by conducting a thought experiment: suppose a sunspot hits the economy and firms increase their investment spending without any change in the economy's fundamentals justifying it. Could this investment boom be potentially consistent with equilibrium? The answer is yes and the reason is simple. Investment has counteracting effects on the determination of the marginal cost. It increases current marginal cost but it reduces marginal cost in subsequent periods. The resulting inflation dynamics inherit the U-shaped marginal cost pattern. In particular, there will be some period of deflation in the aftermath of the investment boom. To the extent that the central bank follows the Taylor principle, the associated real inter-

[14]The indeterminacy region associated with the case where the Taylor principle is met does not lend itself for a simulation of the sunspot since the order of indeterminacy is two. For a discussion of the last point see Galí (1997) and the references herein.

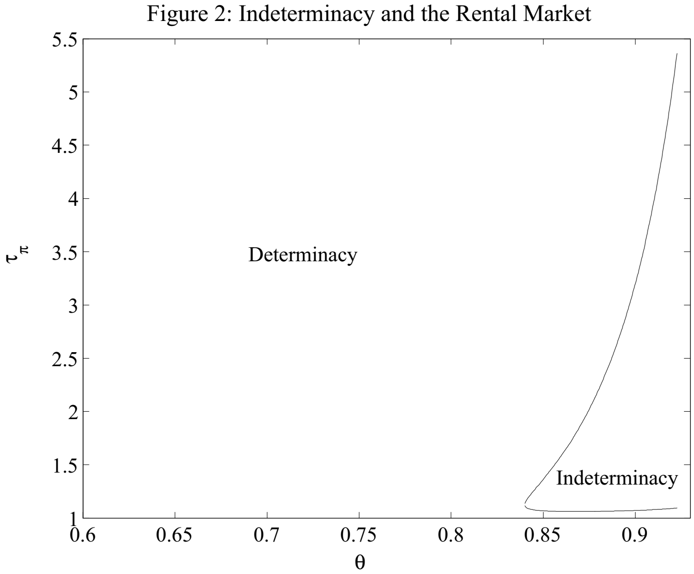
est rate will therefore drop, for some time. The latter could potentially dominate the long real interest rate relevant for investment. If this happens, then it may rationalize the investment boom ex post.

Whether this possibility materializes, or not, depends on both the price stickiness parameter and the inflation response coefficient, as shown in Figure 1. Let us develop the intuition. First, we note that some price stickiness is needed for the above reasoning to make sense: if prices were assumed to be flexible then the real marginal cost would be constant. Indeed, a price stickiness parameter, θ, of about 0.63 is needed to obtain indeterminacy under an interest rate rule that respects the Taylor principle. This value corresponds to an average lifetime of a price of less than 3 quarters. Of course, the exact extent to which prices are sticky in actual economies remains controversial.[15] However, a value of θ as high as 0.75 is often considered to be empirically plausible. Second, we analyze the comparative statics associated with a change in the inflation response coefficient. Let us assume that price stickiness is such that the Taylor principle does not guarantee determinacy and consider three alternative arrangements for the conduct of monetary policy. In each of them the inflation response coefficient is assumed to be strictly larger than one implying that the Taylor principle is satisfied. The three rules differ, however, in the assumed aggressiveness of monetary policy. We consider a weak case (a), an intermediate case (b) and an aggressive case (c), as measured by the relative size of the respective inflation response coefficients. Consider case (a) (the weak case) and suppose that there is a drop in the relevant long real interest rate along the lines outlined above. Under the maintained assumption regarding the conduct of monetary policy the resulting decrease in the long real interest rate will not be large enough to justify the investment boom ex post. As a result, REE is determinate. This is different in case (b) (the intermediate case). A sufficiently large response parameter implies a decrease in the long real rate that is large enough to justify the investment boom

[15] The micro evidence in Golosov and Lucas (2003) suggests that firms change prices more frequently than every 2 quarters, while 4 quarters appear to be plausible based on Taylor (1999b).

ex post. This means that REE is indeterminate. The situation changes again in case (c) (the aggressive case). We observe that the central bank is more effective in reducing future deflation than in reducing current inflation. The reason is that an increase in the response parameter decreases future deflation, which in itself tends to increase current inflation. Hence, if monetary policy is sufficiently aggressive and future expected deflation is small, then the relevant long real interest rate must increase rather than decrease. As a result, REE is determinate.

Figure 2: Indeterminacy and the Rental Market



As we have argued, forward-looking price setting is one key economic mechanism behind our result that the Taylor principle is a poor guide for the design of monetary policy rules. Indeed, to the extent that a rental market for capital is assumed price setting is not forward-looking enough to imply indeterminacy, unless extreme assumptions regarding the frequency of price adjustments are made. This is shown in Figure 2. These findings are consistent with those reported by Carlstrom and Fuerst (2003).

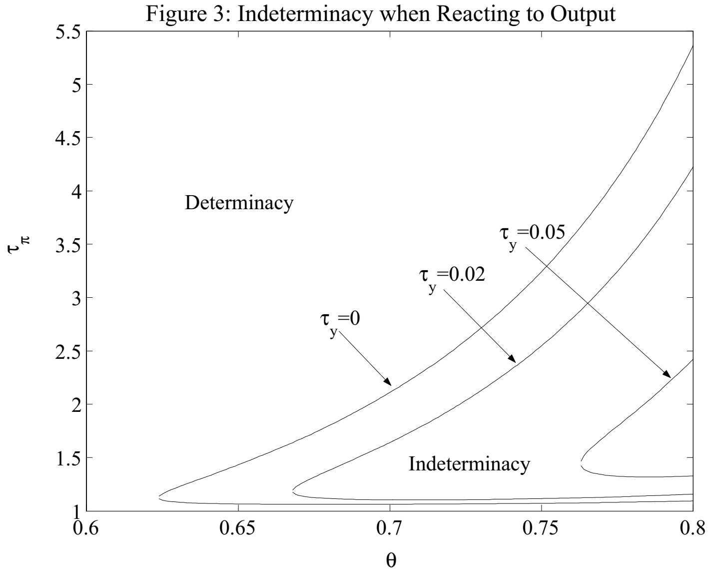
In summary, abstracting from capital accumulation, i.e. considering only consumption demand, which does not produce any counteracting effects for the determination of the marginal cost, or using the rental market assumption, which reduces the effective price stickiness in the model, obscures the fact that the Taylor principle is not a useful guide for the design of monetary policy. What form should simple interest rate rules then take in order to prevent the central bank from becoming a source of macroeconomic instability?

3.3 The Importance of Responding to Economic Activity

It is natural to consider next the determinacy regions associated with an interest rate rule that allows for an output response:

$$i_t = \rho + \tau_y y_t + \tau_\pi \pi_t. \tag{26}$$

Figure 3: Indeterminacy when Reacting to Output



The result is shown in Figure 3. A relatively small size of the output response coefficient is enough to reduce dramatically the importance of the indeterminacy issue. The intuition is as follows: an investment boom increases current output. If the central bank reacts with its interest rate instrument directly to this, then chances are much smaller that the impact of current investment spending on future marginal cost leads to a monetary policy which would justify an investment boom ex post. The last result has interesting implications for the design of monetary policy rules. Schmitt-Grohé and Uribe (2004) emphasize that reacting to output is costly in welfare terms. This is shown for a very rich set of DNK models. We amend their finding with a caveat: based on our analysis reacting to some measure of real activity appears to be recommendable since it reduces the risk that the central bank becomes a source of unnecessary fluctuations in the economy. Clearly, these issues need to be further explored by conducting a welfare analysis for a DNK model with firm-specific investment.

4 Conclusion

According to the Taylor (1999) principle a central bank should adjust the nominal interest rate by more than one for one in response to changes in current inflation. This recommendation is generally believed to be a useful guide for the design of monetary policy. Our main result is in stark contrast with this view. We find that by following the Taylor principle a central bank does not necessarily avoid becoming a source of marcoeconomic instability. More importantly, to the extent that a central bank adjusts the nominal interest rate *only* in response to inflation, indeterminacy appears to be the regular case. This finding challenges much of the conventional wisdom regarding desirable properties of interest rate rules.

Our result follows from a interaction of two economic mechanisms: forward-lookingness in investment and in price setting. In explaining these mechanisms we build on our earlier work where Sveen and Weinke (2003, 2004a,b) solve and discuss models with firm-specific capital and Calvo pricing. Based on our insights we make the case for interest rate rules prescribing that the central bank should react to some measure of economic activity, in the spirit of the rule that has been originally proposed by Taylor (1993).

Appendix: Inflation Dynamics

Woodford (2004) posits that the price chosen by a Calvo price setter i is:

$$\widehat{p}_t^* (i) = \widehat{p}_t^* - \tau_1 \widehat{k}_t (i) , \tag{A1}$$

where τ_1 is an unknown parameter. He further assumes that the investment decision of any firm j satisfies:

$$\widehat{k}_{t+1} (j) = \tau_2 \widehat{k}_t (j) + \tau_3 \widehat{p}_t (j) , \tag{A2}$$

where τ_2 and τ_3 are two additional unknown parameters.

Finally, he invokes the relationship between the log-linearized average newly set price, $\widehat{p}_t^*$, and inflation, π_t:

$$\pi_t = \frac{1-\theta}{\theta} \widehat{p}_t^* . \tag{A3}$$

Combined with the first-order conditions for price setting and investment it is possible to pin down the unknown coefficients τ_1, τ_2, and τ_3 and to derive the inflation equation (21), along the lines outlined in Woodford (2004).

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