Monetary indicators and policy rules in the P-star model

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Discussion paper 18/02

Economic Research Centre

of the Deutsche Bundesbank

June 2002

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ISBN 3–935821–21–2

Abstract

There is a broad consensus among economists that, in the long run, inflation is a monetary phenomenon. However, monetary policy is often analysed using models that have no causal role for monetary aggregates in the propagation of inflationary processes. Moreover, impulses from monetary policy actions are transmitted to inflation through the output gap alone. This paper analyses monetary indicators and monetary policy rules within the framework of a small monetary model, the P-star model. In this model monetary aggregates play an active role in the transmission mechanism of monetary policy actions. Interest rate impulses affect inflation through two channels, the output gap and the liquidity gap.

Section 2 of the paper analyses monetary indicators of inflation. Using a long-run money demand function, three monetary indicators are discussed: the monetary overhang, the price gap, and the nominal money gap. The price gap is a comprehensive indicator of inflationary pressure, combining information from the aggregate goods market (output gap) and the money market (liquidity gap). Some implications of using the price gap in Phillips-type equations for the dynamics of inflation are discussed as well.

Section 3 analyses the role of the price gap in the monetary transmission process more closely. The P-Star model and a New-Keynesian-Taylor-type model are compared with respect to their stability properties, implied sacrifice ratios and the efficiency of interest rate policy in stabilising inflation and output fluctuations.

Section 4 explores a range of monetary policy rules within the P-star model. First, direct inflation targeting, inflation forecast targeting, and optimal inflation targeting are analysed and contrasted with a strategy of price-level targeting, often suggested as an alternative to inflation-based rules. Second, assuming a more general loss function for the central bank, a Taylor rule (focussing on inflation and output), monetary targeting and a two-pillar strategy (focussing on monetary growth and inflation) are analysed. The performance of these rules is investigated under perfect foresight and rational expectations of the central bank. Moreover, these strategies are compared to two benchmarks, a passive rule and a broadly based meta-strategy. Finally, monetary targeting as an intermediate targeting strategy is compared to a Taylor rule when the central bank has an information advantage with respect to monetary growth.

Zusammenfassung

Unter Ökonomen besteht ein breiter Konsensus dahingehend, dass Inflation auf lange Sicht ein monetäres Phänomen ist. Gleichwohl wird die Geldpolitik häufig im Rahmen von kleinen Modellen analysiert, in denen die Geldmenge in keinem kausalen Zusammenhang zur langfristigen Entwicklung des Preisniveaus steht. Die Transmission geldpolitischer Impulse erfolgt nur über den Auslastungsgrad. In diesem Papier werden monetäre Indikatoren und geldpolitische Regeln im Rahmen eines kleinen monetären Modells analysiert, des P-Stern – Modells. In diesem Modell spielen monetäre Aggregate eine aktive Rolle im Transmissionsprozess geldpolitischer Impulse. Die Zinspolitik der Notenbank beeinflusst die Inflationsentwicklung über zwei Kanäle, den Auslastungsgrad und den Liquiditätsgrad.

Im Abschnitt 2 werden monetäre Indikatoren der Inflationsentwicklung diskutiert. Ausgehend von einer langfristigen Geldnachfragefunktion werden der Geldüberhang, die Preislücke und die nominale Geldlücke verglichen. Die Preislücke ist ein umfassender Inflationsindikator, der den vom Gütermarkt (Auslastungsgrad) und vom Geldmarkt (Liquiditätsgrad) ausgehenden Inflationsdruck zusammenfasst. Ferner werden die Implikationen der Preislücke in Phillips-Beziehungen für die Inflationsdynamik diskutiert.

Der Abschnitt 3 befasst sich eingehender mit der Rolle der Preislücke im monetären Transmissionsprozess. Das monetäre P-Stern – Modell and ein Neu-Keynesianisches Modell des Taylor – Typs werden im Hinblick auf ihre Stabilitätseigenschaften, die stabilitätspolitische Effizienz der Zinspolitik sowie die Kosten einer Disinflationspolitik verglichen.

Der Abschnitt 4 untersucht eine Reihe geldpolitischer Regeln im P-Stern – Modell. Die direkte Inflationsteuerung, die Inflationsprognosesteuerung sowie die optimale Inflationssteuerung werden untersucht und mit einer Strategie der Preisniveausteuerung verglichen. Ausgehend von einer allgemeineren Zielfunktion für die Notenbank werden ferner eine Taylor – Regel (Steuerung von Inflation und Output), die Geldmengensteuerung sowie eine Zwei-Säulen-Strategie (Steuerung von Geldmengenwachstum und Inflation) untersucht. Das Abschneiden dieser Regeln wird für den Fall perfekter Voraussicht sowie rationaler Erwartungen seitens der Notenbank analysiert. Außerdem werden diese Strategien mit zwei Benchmark – Strategien verglichen, einer passiven Regel sowie einer breit angelegten Meta-Strategie. Abschließend wird die Geldmengensteuerung als Zwischenzielstrategie mit einer Taylor-Regel verglichen, wenn die Notenbank einen Informationsvorsprung bezüglich des Geldmengenwachstums besitzt.

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1. Introduction

"These days, few economists would disagree with the statement that inflation is a monetary phenomenon in the long run. Indeed, this statement is one of the central tenets of economic theory. The long-run relationship between money and prices has been confirmed by an impressive number of empirical studies, both across countries and across time."[1] Even so, analyses of monetary policy are often based on a Neo-Keynesian Taylor-type model, in which money plays no part in the propagation of inflationary processes and monetary policy impulses spread solely via the real demand for goods. This is not satisfactory from a theoretical point of view, nor does it reflect the empirical evidence for the euro area. In the P-star model, the money stock plays a causal role in the transmission process of monetary impulses and monetary policy has an impact on economic development both through the real demand for goods and via the demand for money.

This paper investigates monetary indicators and monetary policy rules on the basis of the P-Star model. Starting with a long-term money demand function, chapter 2 discusses alternative monetary indicators for price developments: the monetary overhang, the price gap and the nominal money gap. Chapter 3 investigates the role of the price gap in the monetary transmission process, the relative efficiency of inflation and output stabilisation in the Taylor and the P-star models, and the costs of a disinflationary policy. Chapter 4 discusses the behaviour of various monetary policy rules (inflation targeting, price-level targeting, the Taylor rule, monetary targeting and a two-pillar strategy) in the context of the P-star model. Chapter 5 contains a summary with conclusions.

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* The opinions expressed in this paper do not necessarily reflect the views of the Deutsche Bundesbank. I wish to thank my colleagues at the Research Centre, the participants in a Friday seminar and, in particular, Hans-Eggert Reimers and Franz Seitz for their extremely helpful comments. Any remaining errors and shortcomings are, of course, my own.

1 Issing (2001, p 5). On the ECB's monetary policy strategy, see European Central Bank (1999, 2000) and on the Bundesbank's monetary policy strategy, see Issing (1994) and König (1996).

2. Monetary indicators of price developments

> *"Accuracy and precision are not the only determinants of the usefulness of measurements in policymaking. The conceptual framework that defines and constrains what is measured and how it is measured establishes the effectiveness and usefulness of those measurements." (Humphrey 2001)*

The production function and the money demand function are important components of macroeconomic models. The production function characterises the production process and the money demand function characterises the transaction process of an economy. A production function is often used for determining potential output and the degree of capacity utilisation. In this paper, a money demand function is used to complement potential output by a monetary equilibrium variable – the equilibrium price level. The price gap, i.e. the difference between the equilibrium price level and the current price level is an indicator of inflationary pressure reflecting both the real economic factors (output gap) and monetary effects (liquidity gap).[2] This indicator combines – roughly speaking – the excess demand for goods (realised demand) and the excess supply of money (potential demand).

2.1 Money demand: The cornerstone of the following analysis of monetary indicators of price developments is the assumption that a stable long-term money demand function exists which is homogenous in terms of prices:[3]

(2.1) $$m^d = p + ß\, y - \gamma\, i$$

To simplify the notation, the time index (t) for variables is mostly omitted, as is the explicit statement of level constants. With the exception of i, lower-case letters designate the natural logarithms of the variables having the matching upper-case letters. M^d is the money demand, P the price level and Y real output. The opportunity costs of cash holdings (i) may be a long-term interest rate or - in the case of broad monetary aggregates - an interest-rate differential. The signs are stated explicitly; the coefficients themselves are therefore to be regarded as absolute values: ß is the income elasticity and γ is the semi-interest-rate elasticity of money demand.

2 For the measurement of surplus liquidity, see also Köhler and Stracca (2001).

3 For the derivation of money demand functions from a microeconomic optimisation approach, see Woodford (1996). Lucas (1996) discusses price homogeneity and long-term neutrality of money. Sriram (2001) gives an overview of recent empirical studies, Serletis (2001) analyses micro-based (Divisa) aggregates.

2.2 Monetary overhang: Owing to information and adjustment costs, the money stock (M) available at any given time may differ from the demand for money. The relative difference between the money stock and money demand is described as monetary overhang (u):

(2.2) $$m = m^d + u$$

The monetary overhang is an indicator of disequilibria on the money market. It expresses the differences between the existing money holdings and the demand for money holdings resulting from the current economic situation (measured by y and i). If the money demand function forms a stable cointegration relationship, the monetary overhang is a stationary variable (error correction term) which contains information on the future development of the money stock. Dynamic processes of adjustment ensure that, following a disturbance, the money holdings adjust to the path defined by the money demand (Engle and Granger 1987).

2.3 Price gap: The equilibrium money stock (M*) is defined as the money stock demanded given the prevailing general price level if both the goods and the money markets were in equilibrium:

(2.3) $$m^* = p + ß\, y^* - \gamma\, i^*$$

where Y* is potential output and i* the equilibrium interest rate.[4] The relative difference between the current money stock and the equilibrium money stock is described as the money gap:[5]

(2.4) $$m - m^* = ß(y - y^*) - \gamma(i - i^*) + u$$

Instead of measuring these disequilibria in units of the (logarithmic) money stock, they can also be expressed in an equivalent manner in units of the (logarithmic) price level. To do this, the equilibrium price level (P-star) is defined as the price level that would emerge given the current holdings of money if both the goods market and the money market were in equilibrium:

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4 On the estimation of potential output, see McMorrow and Roeger (2001), Alvarez et al (2000) as well as Tödter and von Thadden (2000).

5 Svensson (2000) refers to the money gap as the real money gap: m – m* = (m-p) – (m* – p). The value of this extension is doubtful, however, as any other variable could be inserted instead of p.

$$p^* = m - \beta\, y^* + \gamma\, i^* \tag{2.5}$$

The equilibrium price level is thus an indicator of the level of goods prices that would emerge over the longer term given the existing money stock if the disequilibria (y - y*, i - i*, u) had disappeared. As may easily be seen, the price gap and the money gap are identical:

$$p^* - p = \beta(y - y^*) - \gamma(i - i^*) + u = m - m^* \tag{2.6}$$

This reflects the fact that inflation, in the long term, is a monetary phenomenon. Upward price pressure may result from the combination of three factors: the utilisation of production capacity is high (capacity pressure), the interest-rate level is lower than in equilibrium (interest-rate pressure) or a monetary overhang exists (money supply pressure).

Hallman et al (1989, 1991) originally derived the price gap from the quantity equation ($p + y = m + v$) and defined the equilibrium velocity of circulation of money as $v^* = p^* + y^* - m$. This results in a breakdown of the price gap into the output gap and the liquidity gap:

$$p^* - p = (y - y^*) + (v^* - v) \tag{2.7}$$

The liquidity gap indicates inflationary pressure if the velocity of circulation of money is smaller – i.e. cash holdings are higher – than in equilibrium. In conjunction with (2.1), it may be demonstrated that the liquidity gap consists of three components:

$$v^* - v = (\beta - 1)(y - y^*) - \gamma\,(i - i^*) + u \tag{2.8}$$

The first component is a spill-over effect from the goods market which emerges if the income elasticity of the money demand deviates from one. The two other components are interest-rate pressure and money supply pressure.[6]

2.4 Nominal money gap: The nominal money gap is an indicator of the (cumulative) deviations of the money stock from the monetary target. Assume that the central bank sets itself the inflation target $\hat{\pi}_t$ for each period. Starting from a base period (t = 0), the implied

[6] Some authors determine the equilibrium price level using a time series approach from the trend of output and the velocity of circulation of money, with Groeneveld (1998) applying a Kalman filter, whereas Scheide and Trabandt (2000) use the Hodrick-Prescott filter.

price level target is defined as the accumulation of the inflation targets: $\hat{p} = p_o + \sum \hat{\pi}_\tau$. On account of (2.1), a target level for the money stock consistent with this is:

(2.9) $$\hat{m} = \hat{p} + \beta y^* - \gamma i^*$$

The nominal money gap is the relative difference between the current money stock and the central bank's implicit monetary target. This indicator thus measures the cumulative deviations from the monetary target. As may be seen from

(2.10) $$m - \hat{m} = (p - \hat{p}) + (p^* - p)$$

the nominal money gap is made up of the "price target gap" and the price gap. The nominal money gap is not a suitable indicator of future inflation potential, since it contains price rises that have already been realised.

In terms of their informative value for the development of inflation, there is a systematic relationship between the monetary indicators. The monetary overhang measures inflation potential resulting from a disquilibrium on the money market. The price gap (money gap) captures the inflation potential resulting from disequlibria on the money and goods markets. The nominal money gap is a performance indicator of monetary targeting.

Table 2.1: Monetary indicators and their components

	Future inflation potential (p* - p)				**Realised Excessive Inflation**
	Liquidity pressure (v* - v)			**Capacity pressure**	
	Money supply pressure u	Spill-over (ß-1)(y-y*)	Interest-rate pressure - γ (i - i*)	(y – y*)	$(p - \hat{p})$
Monetary overhang					
Price gap (or money gap)					
Nominal money gap					

The P-star approach links disequilibria on the goods and money markets to form a consistent and comprehensive indicator of inflationary pressure. The price gap is thus a potentially important variable for explaining and forecasting inflation. The price gap may also be useful, however, as part of a broader system of indicators for analysing economic developments in other areas. **Annex A** demonstrates how the price gap can be used for constructing an indicator for the labour market and the foreign exchange market. Furthermore, it is shown how the balance of the government sector can be broken down into a structural and a cyclical component using the output gap and the price gap.

2.5 Price dynamics: If the price gap is a useful indicator of potential inflation, it should play a part in helping to explain inflation dynamics and, in the long run, determine the development of the general price level. This contrasts with microeconomic approaches in which the optimum price level of an enterprise (indexed by i) producing under monopolistic competition is proportionate to the marginal costs of production

(2.11) $$\tilde{P}_i = \mu \frac{\partial C(Y_i)}{\partial Y_i}$$

where μ (≥ 1) is a mark-up factor which depends on the price elasticity of demand. Under certain assumptions, such cost-pressure approaches may be used to derive an aggregated Phillips relationship for the inflation rate as a function of inflation expectations, the degree of capacity utilisation and the supply shock:[7]

(2.12) $$\Delta p = \Delta p^e + \lambda(y - y^*) + \upsilon$$

These approaches may explain the relative prices, but not persistent changes in the general price level. Cost increases or supply shocks, which affect all firms equally, can be passed on to the product prices on a lasting basis only under certain underlying macroeconomic conditions. If all enterprises want to change their prices, it is possible that none of them ultimately succeeds in doing so, as Humphrey (1998, p 54) states, *"Here then is the cost-push fallacy: it confounds relative with absolute prices and sectoral real shocks with economywide nominal ones. It says nothing about money's role in price determination."* Inflation in these approaches is a non-monetary phenomenon.

Corporate pricing policy is embedded in the macroeconomic environment. Rational enterprises set their prices not only with an eye to the corporate optimum (2.11). They also take due account of the opportunity costs that arise if price formation does not pay attention to the underlying macroeconomic conditions set by monetary policy. In the approach by Rotemberg (1982), the firms weigh up the costs of price changes against the costs caused by deviations from their equilibrium price. If the deviations from both the corporate

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[7] See Gali and Gertler (1999), Gali et al (2001) as well as Mehra (2000). Roberts (1998) explains the relationship between alternative Neo-Keynesian approaches.

equilibrium $(\tilde{P}_i)$ and from the macroeconomic equilibrium (P*) are taken into account, the following optimisation approach is obtained

(2.13) $$\min_{p_{it}} K_{it} = E_t \sum_{\tau=t}^{\infty} \theta^{\tau-t} \left[\kappa(p_{i\tau} - \tilde{p}_{i\tau})^2 + \eta(p_{i\tau} - p^*_{\tau})^2 + (p_{i\tau} - p_{i\tau-1})^2 \right]$$

where K is an index of the total costs, p_i is the current price, $\tilde{p}_i$ is the corporate equilibrium price and p* is the macroeconomic equilibrium price level – all in logs. θ is a constant discounting factor, κ and η are parameters which measure the amount of the disequilibrium costs in relation to the costs of price changes. The first-order condition gives the following expression:

(2.14) $$E_t \left\{ \kappa(p_{it} - \tilde{p}_{it}) + \eta(p_{it} - p^*_t) + (p_{it} - p_{it-1}) - \theta(p_{it+1} - p_{it}) \right\} = 0$$

From this is obtained:

(2.15) $$\Delta p_{it} = \theta E_t \Delta p_{it+1} + \kappa(\tilde{p}_{it} - p_{it}) + \eta(p^*_t - p_{it})$$

Fluctuations in the marginal production costs are often approximated by changes in the output gap. If $\tilde{p}_{it}$ is substituted by $p_{it} + \gamma(y_{it} - \bar{y}_t) + \upsilon / \kappa$, where $y_{it} - \bar{y}_t$ designates the deviations from the average level of output and υ a non-firm-specific shock term (Roberts 1995). If the discounting factor is set approximately at one, the expectation operator is replaced by a higher-case e and the time index is omitted, (2.15) may be written more compactly as

(2.16) $$\Delta p_i = \Delta p_i^e + \lambda(y_i - \bar{y}) + \eta(p^* - p_i) + \upsilon$$

where $\lambda = \kappa\, \gamma$. The inflation rate of enterprise i depends on the expected inflation rate, the relative demand situation which the enterprise faces, on the difference vis-à-vis the equilibrium price level and on price shocks which affect all enterprises. The future inflation rate appears in (2.16) owing to price rigidities. If the demand faced by the enterprise i is designated as $y_i = \bar{y} + \varepsilon_i$, it follows from (2.16) for the relative price changes

(2.17) $$\Delta(p_i - p_j) = \Delta(p_i^e - p_j^e) + \lambda(\varepsilon_i - \varepsilon_j) - \eta(p_i - p_j)$$

Hence, the relative price changes depend on the relative inflation expectations and the relative demand shocks. Differences in the relative prices are temporary. Factors affecting all enterprises in the same way do not have an impact on the relative prices. By contrast, the aggregate inflation rate is solely a function of macroeconomic determinants, inflation expectations and the price gap:

$$\Delta p = \Delta p^e + \eta\,(p^* - p) + \upsilon \qquad (2.18)$$

In this setting, price adjustment processes take place until an equilibrium is achieved on the goods and money markets. The money stock has an influence on the emergence and propagation of inflationary processes. The price gap ensures that the uncoordinated sales plans of the enterprises adjust in the longer term to demand in the economy as a whole. This has important implications for the transmission of monetary policy impulses. In traditional Phillips relationships, monetary impulses have an impact on the inflationary process only through the real demand for goods. In the extended Phillips relationship (2.18), monetary impulses can also have an effect on price developments by means of their liquidity effects. Cost or productivity shocks, which affect all enterprises, have a lasting impact on the general price level only if they are accommodated monetarily. Conversely, an abundant provision of liquidity may have inflationary effects before it is reflected in real demand. With regard to the P-star approach, Baltensperger (2000, p 105) points out that a price-adjustment equation of this kind does not have a macroeconomic foundation which is beyond all doubt, although this applies equally to alternative price-adjustment equations and, in particular, to the Phillips curve formula preferred by Svensson and the standard macroeconomic approach.

Under discussion in recent times have been approaches which explain price developments not in terms of costs or demand, but – by analogy with the valuation of assets – by the ratio of government debt to the expected discounted value of future budgetary surpluses. **Annex B** will briefly go into the fiscal theory of the price level.

3. The price gap in the monetary transmission process

> *"It has recently become common practice – indeed, virtually standard practice – for monetary policy analysis to be conducted in models that include no reference to any monetary aggregate." (McCallum (2001)*

Monetary policy is increasingly being studied using small macroeconomic models in which monetary aggregates do not play an active role.[8] This applies, for example, to the models used by Svensson (1997, 1998, 1999a), Blinder (1998) and Bernanke et al (1999) for analysing inflation targeting. However, there are not just theoretical grounds for inflation, in the long run, being a monetary phenomenon. The empirical evidence available for the euro area also suggests that the price gap is a relevant variable for explaining the dynamics of inflation. Whereas price adjustment in the Taylor model is determined by the degree of capacity utilisation, in the P-star approach it depends on the difference between effective money holding and that desired in the long term. Below, small macro-models are used to illustrate for a closed economy the implications which the inclusion of the price gap in the Phillips relationship has for the transmission process of monetary policy impulses and the efficiency of monetary policy.

3.1 Taylor model: Following Taylor (1999), a small stylised Neo-Keynesian macro-model is described by the following three equations[9]

$$y_t = y_t^* - \alpha(i_t - \Delta p_t - r) + \varepsilon_t \qquad (3.1)$$

$$\Delta p_t = \Delta p_{t-1} + \eta(y_t - y_t^*) + \upsilon_t \qquad (3.2)$$

$$i_t = r + \hat{\pi} + g(\Delta p_{t-1} - \hat{\pi}), \qquad \alpha, \eta, g \geq 0 \qquad (3.3)$$

where (3.1) is an aggregate demand function, (3.2) is a simple Phillips relationship for inflation dynamics and (3.3) is a monetary policy reaction function. The nominal interest rate i is simultaneously the monetary policy instrument variable, i.e. no distinction is made between long and short-term interest rates.[10] Furthermore, Δp is the inflation rate, r the (constant) real interest rate and $\hat{\pi}$ the central bank's inflation target. Real demand depends on the real interest rate, the inflation rate on the output gap, and the central bank's interest-

[8] McCallum (2001) discusses "monetary policy analysis without money", Clarida et al (1999) treat the "science of monetary policy" with a model in which neither money demand not money supply occur.

[9] Clarida et al (1999) discuss a similar model with forward-looking expectations.

[10] Baltensperger (2000) and Hetzel (2000) criticise this and other assumptions of the Taylor model.

rate policy reacts to observed deviations from the inflation target, i.e. it is a form of direct inflation targeting. The demand shocks (ε) and price/supply shocks (υ) are non-autocorrelated and distributed independently with zero mean and constant variances.

In the long-run equilibrium (if it exists) y = y*, $\Delta p = \hat{\pi}$ and $i = r + \hat{\pi}$. So that the inflation rate is identical in equilibrium with the inflation target, it is crucial that the central bank uses the "true" real interest rate (r) in the reaction function. If the constant term in the reaction function diverges from the real interest rate, the system – even if it is stable – will tend to an equilibrium value that may deviate sharply from the inflation target.[11] The money stock does not play an active role in this model. The model could be supplemented by a money demand function, which would not make the slightest difference to the results. Monetary policy impulses are transmitted solely via the interest rate and the output gap to the inflation rate. The model (3.1 - 3.3) produces, as a reduced form for the inflation rate, the following dynamic relationship[12]

$$\Delta p_t = \hat{\pi} + \frac{1-\eta\alpha g}{1-\eta\alpha}(\Delta p_{t-1} - \hat{\pi}) + \frac{1}{1-\eta\alpha}\omega_t \tag{3.4}$$

where $\omega_t = \eta\varepsilon_t + \upsilon_t$ is a stochastic term reflecting demand shocks and supply shocks. How strongly the central bank reacts to deviations from the monetary target is crucial to the stability of the Taylor model. Given a passive monetary policy $(g = 0)$, the coefficient of the lagged inflation rate is greater than one. Thus, the process (3.4) is dynamically unstable. But even a moderate active monetary policy with $0 < g \le 1$ is not enough to stabilise the inflation process. The system can be stabilised only if the central bank reacts disproportionately $(g > 1)$ to deviations from the inflation target. This is necessary in order for an interest-rate increase to bring about a rise in the real interest rate. Interest-rate policy is all the more effective, the more interest-elastic the demand for goods is and the more strongly the inflation rate reacts to changes in the output gap. The system is dynamically unstable if even only one of the three conditions fails: $g > 1$, $\alpha > 0$, $\eta > 0$.

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[11] If the central bank sets the real interest rate at $r_o \neq r$, the equilibrium inflation rate is then $\pi_o = \hat{\pi} + (r - r_o)/(g-1)$. If g lies in the proximity of one, small errors in the estimation of the real rate of interest may lead to major deviations in the inflation target. Monetary policy then possesses an inflationary or deflationary bias, even if it does not pursue an output target deviating from potential output.

[12] Laidler (2002) discusses the introduction of the money stock into the equation for real demand in the form of a real balance effect or a credit channel. This would, however, make no change to the fact that monetary policy acts only through one channel: real demand.

In an empirical study for 17 industrial countries, Goodhart and Hofmann (2000) estimate aggregate demand equations (IS curves) and price equations (Phillips curves). This reveals that, although inflation dynamics in most countries depend on the output gap, interest-rate policy impulses do not even overcome the first hurdle of the transmission channel *"since it was not possible in almost all cases to detect any significant effect of the short-term real interest rate on the output gap"* (p 16). Nelson (2001) describes this evidence as the *IS puzzle*. In contrast, Favara and Giordani (2002) provide evidence that money demand shocks have substantial and persistent effects on output and prices. The suitability of the Taylor model as a standard model for analysing monetary policy is therefore called into question also from an empirical point of view.

3.2 P-star model: The P-star model incorporates the money market into the analysis and assigns an active role to the money stock. Prices react to changes in the output gap and the liquidity gap, i.e. to disequilibria on the goods and money markets. In formal terms, the P-star model is obtained if the output gap is replaced by the price gap in equation (3.2) of the Taylor model and equation (2.6) for the price gap is added:

(3.1) $$y_t = y_t^* - \alpha(i_t - \Delta p_t - r) + \varepsilon_t$$

(3.2') $$\Delta p_t = \Delta p_{t-1} + \eta(p_t^* - p_t) + \upsilon_t$$

(3.3) $$i_t = r + \hat{\pi} + g(\Delta p_{t-1} - \hat{\pi})$$

(3.5) $$p_t^* - p_t = \beta(y_t - y_t^*) - \gamma(i_t - r - \hat{\pi}) + u_t$$

The reduced form for the inflation process is now:

(3.6) $$\Delta p_t = \hat{\pi} + \frac{1 - \eta(\alpha\beta + \gamma)g}{1 - \eta\alpha\beta}(\Delta p_{t-1} - \hat{\pi}) + \frac{1}{1 - \eta\alpha\beta}\omega_t$$

The reduced-form disturbance term is $\omega_t = \eta\beta\varepsilon_t + \eta u_t + \upsilon_t$. In contrast to the Taylor model, monetary policy acts through two channels. The first transmission channel runs from interest rates via the real demand for goods and the output gap to the inflation rate. In the second transmission channel, interest rates have an impact on inflation dynamics via money demand and the liquidity gap.

With a passive monetary policy, the P-star model is also unstable. In this model, however, no disproportionate reaction of the nominal interest rates is needed to stabilise the system when there are deviations from the inflation target. In fact, it is sufficient if:

(3.7) $$g > \frac{\alpha\beta}{\alpha\beta + \gamma}$$

Thus, values for the monetary policy reaction coefficient which are smaller than one can stabilise inflation.[13] By way of illustration, the following parameter values are assumed:

Interest elasticity of aggregate demand:	$\alpha = 0.5$
Income elasticity of money demand:	$\beta = 1.3$
Interest elasticity of money demand:	$\gamma = 0.7$
Reaction of inflation to disequilibria:	$\eta = 0.2$

This calibration is broadly consistent with empirical estimation results for the Euro area. Estimated interest elasticities of demand range from values insignificantly different from zero (Goodhart and Hofmann 2000) to values close to one (Scharnagl 2002). The long run income elasticity and interest rate elasticity of money demand is based on estimates for the macro-econometric multi-country model of the Deutsche Bundesbank (2000). The reaction of the rate of inflation to changes of the output gap and the price gap, respectively, are consistent with estimates of Goodhart and Hofmann (2000), Smets (2000), Gerlach and Svensson (2001), and Scharngal (2002).

This yields the stability condition: $g > 0.48$. In contrast to the Taylor model, in the P-star model stabilising and controlling inflation by means of interest-rate policy is also possible if the demand for goods does not depend on the real interest rate ($\alpha = 0$). Conversely, the stability condition of the Taylor model is obtained as a special case if money demand is not dependent on the interest rate ($\gamma = 0$).

In both models, provided they are stable, the deviations of the inflation rate from the inflation target follow a first-order autoregressive process:

(3.8) $$\Delta p_t - \hat{\pi} = \Omega\,(\Delta p_{t-1} - \hat{\pi}) + \theta\,\omega_t$$

The parameters Ω and θ are given in equations (3.4) and (3.6) for the Taylor model and the P-star model, respectively. Given otherwise identical parameter values, the persistence of the inflation process in the Taylor model is higher than in the P-star model. However, in the P-star model, the inflation process also depends on money demand shocks, which is not the case in the Taylor model. It is therefore not possible to make general statements on the

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13 The second transmission channel may explain why estimated reaction coefficients are often smaller than might be expected for monetary policy rules in the Taylor model; see Clarida et al (1999).

variance of the inflation process and the output process. The (unconditional) variance of the inflation process given the independence of the shocks is:

(3.9) $$\sigma^2_{\Delta p} = E(\Delta p - \hat{\pi})^2 = \frac{\theta^2}{1-\Omega^2}\ \sigma^2_{\omega}$$

In the Taylor model $\sigma^2_{\omega} = \eta^2\sigma^2_{\varepsilon} + \sigma^2_{\upsilon}$, whereas $\sigma^2_{\omega} = \eta^2\beta^2\sigma^2_{\varepsilon} + \eta^2\sigma^2_{u} + \sigma^2_{\upsilon}$ results for the P-star model. The variance of output is

(3.10) $$\sigma^2_{y} = \alpha^2(\Omega - g)^2\,\sigma^2_{\Delta p} + \theta^2\sigma^2_{\varpi}$$

with $\varpi = \varepsilon + \alpha\upsilon$ in the Taylor model and $\varpi = \varepsilon + \alpha(\eta u + \upsilon)$ in the P-star model.

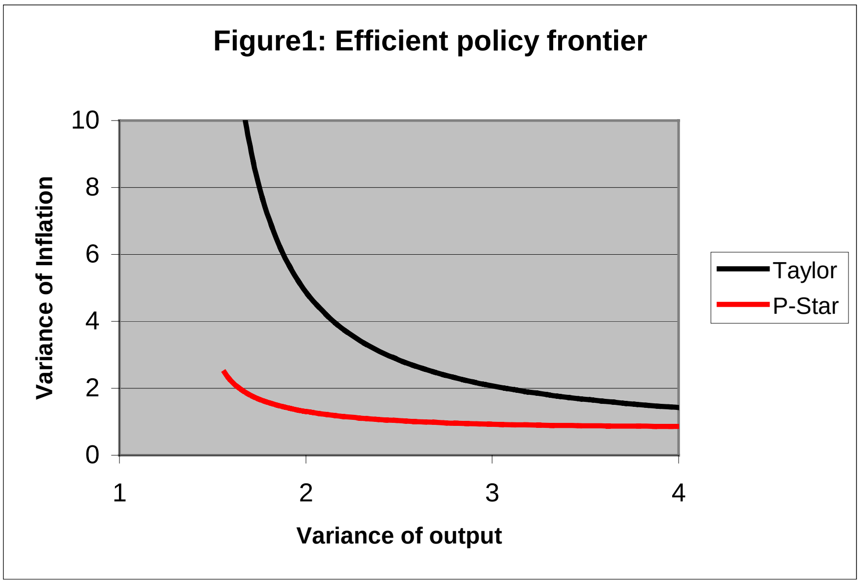
For a numerical illustration, the same parameter values as those above are used. Furthermore, the variance of the demand shock is standardised at 1, the variance of the price shock is set at 0.5 (Smets 2001, Viñals 2001) and the variance of the money demand shock is set at 2 (Deutsche Bundesbank 2000): $\sigma^2_{\varepsilon} = 1$, $\sigma^2_{\upsilon} = 0.5$, $\sigma^2_{u} = 2$. Thus, the persistence parameter of the Taylor (P-star) model becomes Ω = 0.94 (0.68). The variance of the residuals of the reduced form for the inflation process thus amounts in the Taylor model (P-star model) to σ^2_{ω} = 0.54 (0.65). The higher variance in the P-star model is due to the assumed high variance of the money demand shocks. Given g = 1.5, the following values are produced for the variance of the deviations from the inflation target (inflation variance) and the variance of the output gap (output variance):

Table 3.1: Relative efficiency of monetary policy

	Inflation variance	Output variance
Taylor model	6.17	1.87
P–star model	1.61	1.78
g = 1.5		

Given the same reaction function, monetary policy in the P-star model is thus much better able to stabilise the inflation process than in the Taylor model. The more effective stabilisation of the inflation rate comes not at the expense of larger output fluctuations.

If the reaction parameter of monetary policy g is changed step by step, the line of efficient strategies (efficient policy frontier) shown in **Figure 1** is obtained. The upper line shows the trade-off between inflation and output stabilisation for the Taylor model, whereas the bottom line belongs to the P-star model. Accordingly, the trade-off in the P-star model appears much more favourable than in the Taylor model. If inflation dynamics does not depend on the output gap alone, but also on the liquidity gap, interest-rate policy for stabilising the inflation and output process is clearly more effective. In the P-star model, the money stock assumes the active role assigned to it by economic theory and empirical evidence.



In the P-star model, a policy of disinflation is associated with smaller output losses than in the Taylor model. Such output losses are usually measured by the sacrifice ratio. The sacrifice ratio (SR) expresses the cumulative loss in output given a sustained decline in the inflation rate by 1 percentage point. Given a permanent lowering of the inflation target by 1 percentage point, there is a cumulative output loss of $1 / \eta$ percentage point in the Taylor model, as may be seen from (3.2). The smaller the parameter η is, the more rigid is the price-adjustment process, and the output losses are all the greater under the impact of reducing the inflation rates.[14] In the P-star model, the sacrifice ratio is:

[14] Empirical sacrifice ratios for Germany are between 2 and 4; see Tödter and Ziebarth (1999). Buiter and Grafe (2001) analyse disinflation programmes using the sacrifice ratio.

(3.11) $$SR = \frac{1}{\eta} \frac{\alpha(g-1)}{\alpha\beta(g-1)+\gamma g}$$

As can be seen, for $\gamma = 0$ and $\beta = 1$ the sacrifice ratio of the Taylor model is obtained as a special case. Since the second factor in (3.11) is invariably smaller than one, a disinflationary policy in the P-star model is associated with smaller output losses than in the Taylor model. In contrast to the Taylor model, the sacrifice ratio does not depend only on the persistence parameter η, but also on the other structural coefficients of the model. With the previously used parameter values, a sacrifice ratio of 0.91 is obtained, compared with 5.00 in the Taylor model. The smaller output losses of a reduction in the inflation rates is due to the fact that monetary policy in the P-star model has an impact on price developments not only via the output gap but also via the liquidity gap. Table 3.2 gives the sacrifice ratios in both models for some parameter combinations. As can be seen, a stronger reaction by the central bank to deviations from the inflation target (g) leads to a rise in disinflationary costs. A smaller persistence of the inflation process leads – as in the Taylor model – to a decline in the sacrifice ratio.

Table 3.2: Sacrifice ratio

		$\eta = 0.1$	**$\eta = 0.2$**	$\eta = 0.3$
Taylor model		10.00	**5.00**	3.33
P-star model	g = 1.5	1.82	**0.91**	0.61
	g = 2.0	2.44	1.22	0.81
	g = 2.5	2.75	1.38	0.92
$\alpha = 0.5$, $\beta = 1.3$, $\gamma = 0.7$				

3.3 Empirical evidence: The P-star model has empirical relevance under two conditions: a stable long-term money demand function and inflation dynamics driven by the price gap. This requires that the monetary overhang (u) and the price gap (p* - p) are stationary.

Since its development by Hallman et al (1989, 1991), the P-star approach has been investigated in numerous empirical analyses. Hallman et al already noted for the United States that the price gap is a better indicator of inflationary pressure than a series of other criteria. This led to considerable interest in this concept in other industrial countries. The P-star concept was studied in depth at the Bundesbank (Deutsche Bundesbank 1992, Issing 1992, Tödter and Reimers 1994, Issing and Tödter 1995). The P-star approach was also subjected to empirical tests in other OECD countries, including by Tatom (1991), Hoeller and Poret (1991), Kole and Leahy (1991), Atta-Mensah (1996). The results were generally encouraging (Bank of Japan, 1990, p 5): *"In sum, the price gap can be considered useful as* *a simple yet comprehensive indicator of potential upward pressure on prices."* Recently, Herwartz and Reimers (2001) tested the P-star approach with a comprehensive database from 110 countries for the period from 1960 to 1999. The panel–cointegration approach used provides evidence for the existence of cointegration relationships between p and p*, both for the entire sample and separately for the OECD countries and the countries of Latin America.

The empirical evidence also supports the hypothesis of a stable relationship between the money stock and prices in the euro area (Fagan and Henry 1998, Coenen and Vega 2001, Brand and Cassola 2000, Müller and Hahn 2001). Recently, the P-star concept has also been applied to explaining inflation dynamics in the euro area (Scheide and Trabandt 2000, Gottschalk and Bröck 2000, Gerlach and Svensson, 2001, Trecroci and Vega 2000, Altimari 2001). Although the euro area was not characterised by a single monetary policy (albeit a coordinated one) during the sample period of these studies, it is apparent that the P-star concept – despite considerable data uncertainty and aggregation problems – has a notable explanatory power for aggregate inflation development in the euro-area countries.

For example, Gerlach and Svensson (2001) using aggregated quarterly data for the euro area from 1981 to 1998 estimate a long-term money demand function and an equation for price dynamics, where $\pi = \Delta p - \hat{\pi}$:

$$\begin{aligned} p_t^* &= m_t - 1{,}51 y_t^* \\ \pi_t &= \underset{(0,10)}{0{,}35}\ \pi_{t-1} + \underset{(0,05)}{0{,}28}\ (p_{t-1}^* - p_{t-1}) + \delta z_t + res \end{aligned} \tag{3.12}$$

The variable z represents the rates of change in the energy prices. The coefficient of the price gap is statistically highly significant. The output gap possesses no information content for the development of inflation that goes beyond what is explained by the price gap. Gerlach and Svensson (p 2) summarise the results of their study as follows, *"... we find that the so-called P* model has substantial empirical support. Thus, the 'price gap' ... contains considerable information about the future path of inflation. Furthermore, and perhaps surprisingly, the real money gap* (i.e. price gap) *has more predictive power than the output gap."* Scharnagl (2002) arrives at similar findings in a recent study on the P-star approach for the euro area. Fase (2001) also finds a highly significant contribution of the price gap to inflation dynamics in the euro area. These empirical findings confirm the existence of a stable long-term money demand function and underline the importance of the price gap in explaining price dynamics for the euro area.

4. Monetary policy rules in the P-star model

> *"The conclusion that a central bank's strategy is inefficient solely because it assigns a prominent role to monetary growth and monetary analysis seems to me to be inadequate and without justification when put in that form." (our translation from Baltensperger 2001)*

The last chapter investigated the relative efficiency of monetary policy in the Taylor and P-star models given a strategy of direct inflation targeting. In this chapter, the P-star model is used to analyse various monetary policy strategies. The following model is considered:

(4.1) $$y = -\alpha(i - \pi - \rho) + \varepsilon$$

(4.2) $$\pi = \lambda \pi_{-1} + \eta q + \upsilon$$

(4.3) $$q = \beta y - \gamma (i - \rho) + u$$

(4.4) $$\mu = \pi + q - q_{-1}$$

Time indices have been omitted to simplify notation, potential output has been standardised at zero, the price gap is designated by q. Furthermore, the equilibrium nominal interest rate has been abbreviated to $\rho = r + \hat{\pi}$ and the deviations from the inflation target to $\pi = \Delta p - \hat{\pi}$.

The demand equation (4.1) corresponds to equation (3.1). The inflation equation (4.2) is based on the more general form $\Delta p = E(\Delta p) + \eta q + \upsilon$, with expectations being formed at the end of the period t-1 for the period t. Individuals' inflation expectations depend on the most recently observed inflation rate and the central bank's inflation target: $E(\Delta p) = \lambda \Delta p_{-1} + (1 - \lambda)\hat{\pi}$. For λ = 1, inflation expectations are backward looking, for $\lambda = 0$ they are geared solely to the central bank's inflation target. Combining both hypotheses produces (4.2). Equation (4.3) defines the price gap on the basis of the long-term money demand function. In line with (2.1), the rate of growth of the money stock is $\Delta m = \Delta p + \Delta(\beta y - \gamma i + u)$. By analogy, the monetary target is defined as $\hat{\mu} = \hat{\pi} + \Delta(\beta y^* - \gamma \rho)$. The deviations from the monetary target $(\mu = \Delta m - \hat{\mu})$ may therefore be written as in (4.4) as the sum of the deviations from the inflation target and changes in the price gap. A monetary policy reaction function has been omitted for the time being; it is replaced below by alternative loss functions for monetary policy.

In this model, monetary impulses are transmitted through two channels: via real demand for goods and via money demand. The monetary channel is effective if the interest elasticity of money demand differs from zero. The real channel is effective if the interest elasticity of the demand for goods differs from zero. As a reduced form of the P-star model, (4.5) is obtained:

(4.5)
$$\begin{aligned}\pi &= \lambda\theta\pi_{-1} - \theta\psi(i-\rho) + \theta\omega \\ y &= \alpha\lambda\theta\pi_{-1} - \alpha(1+\theta\psi)(i-\rho) + \theta\varpi \\ q &= \alpha\beta\lambda\theta\pi_{-1} - \Xi(i-\rho) + \beta\theta\varpi + u \\ \mu &= (1+\alpha\beta)\lambda\theta\pi_{-1} - (\Xi+\theta\psi)(i-\rho) - q_{-1} + \theta\omega + \beta\theta\varpi + u\end{aligned}$$

where $\psi = \eta(\alpha\beta + \gamma)$, $\theta = (1-\eta\alpha\beta)^{-1}$ and $\Xi = \alpha\beta + \gamma + \alpha\beta\theta\psi$. Furthermore:

(4.5‘)
$$\begin{aligned}\omega &= \eta\beta\varepsilon + \eta u + \upsilon \\ \varpi &= \varepsilon + \alpha\eta u + \alpha\upsilon\end{aligned}$$

First of all, a passive monetary policy is analysed, where the central bank pegs the interest rate at its equilibrium level ($i = \rho$) and does not attempt to make a stabilising intervention in the system.[15] In this benchmark strategy, the variance of the inflation rate amounts to:

(4.6)
$$\sigma_\pi^2 = \frac{\theta^2\sigma_\omega^2}{1-\lambda^2\theta^2}$$

Given the structural parameters of the model, the inflation variance is all the higher, the higher the variance of the shocks and the higher the persistence of the inflation process are $(\sigma_\omega^2, \lambda)$. In principle, these two factors provide handles for the central bank to conduct an active stabilisation policy: Information on the dynamics of the systems and/or an information advantage over individuals about the realisation of future shocks may help to reduce inflation variability. If, moreover, the structural parameters are known, the central bank can choose the strength of its reaction optimally.

4.1 Inflation targeting: What stabilisation effect can be achieved if the central bank conducts an active interest-rate policy with the sole objective of stabilising inflation by minimising the loss function $L = E(\pi^2)$? The following reaction function is obtained:

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15 Owing to the introduction of the persistence parameter λ, the P-star model is stable even with a passive monetary policy if $\lambda < 1 - \eta\alpha\beta$.

(4.7) $$i = \rho + \frac{1}{\theta\psi}[\lambda\theta\pi_{-1} + \theta\,\hat{\omega}]$$

As (4.5) shows, the expression in the square bracket is the conditional inflation forecast for period t: $E(\pi / i = \rho)$, where $\hat{\omega}$ is the forecast by the central bank of the reduced form inflation shock term. The parameter $1/\theta\psi$, which is dependent on all structural parameters of the model, states the optimum intensity of the reaction to the forecast deviations from the inflation target.

If the central bank is able to observe the shocks in period t before it fixes the interest rate, it will have an information advantage over individuals (asymmetric information) and acts with perfect foresight: $\hat{\omega} = \omega$. If the central bank has no information advantage (symmetric information) it forms rational expectations about the level of the shock, i.e. its assumes $\hat{\omega} = E\omega = 0$. Both cases may be combined as $\hat{\omega} = \kappa\omega$. This formulation contains perfect foresight (κ = 1) and rational expectations (κ = 0) as special cases, but also allows other values for κ. If the reaction function is inserted into the reduced form for the inflation rate, it follows that

(4.8) $$\pi = \theta(1 - \kappa)\,\omega$$

In other words, the deviations from the inflation target are either zero (perfect foresight) or a pure random process with zero mean (rational expectations). The variance of the deviations from the inflation target is:

(4.9) $$\sigma_{\pi}^{2} = \theta^{2}(1 - \kappa)^{2}\,\sigma_{\omega}^{2}$$

With perfect foresight, the central bank is in the position to eliminate fluctuations in the inflation rate completely. Predictions of the level of the shock reduce the inflation variance if $0 < \kappa < 2$. In other words, the forecasts must not underestimate or overestimate the scale of the shock by more than 100%. Measured by inflation variance, the optimum policy is more efficient than the passive policy if the following condition is met:

(4.10) $$(1 - \lambda^{2}\theta^{2})(1 - \kappa)^{2} < 1$$

The central bank can stabilise the inflation process successfully if the inflation rates display a certain persistence or if it possesses information on possible realisations of the shock.

Inflation forecast targeting is an heuristic rule in which monetary policy is geared to conditional inflation forecasts but the intensity of the reaction is decided on an ad hoc basis:

(4.11) $$i = \rho + g(\lambda\theta\pi_{-1} + \theta\hat{\omega})$$

Given this strategy, the variance of the inflation rates is:

(4.12) $$\sigma_\pi^2 = \frac{\theta^2\sigma_\omega^2(1-g\psi\theta\kappa)^2}{1-\lambda^2\theta^2(1-g\psi\theta)^2}$$

For g = 0, the variance of the passive interest-rate policy results as a special case, whereas for $g = 1/\theta\psi$ the variance of the optimum policy is obtained.

In direct inflation targeting, monetary policy is geared solely to observed deviations from the inflation target, to which it reacts with an intensity decided on an ad hoc basis ($g\lambda\theta$):

(4.13) $$i = \rho + g(\lambda\theta\pi_{-1})$$

This means that the variance of the inflation rates becomes:

(4.14) $$\sigma_\pi^2 = \frac{\theta^2\sigma_\omega^2}{1-\lambda^2\theta^2(1-g\psi\theta)^2}$$

If the central bank does not possess any information on the level of future shocks, direct inflation targeting – depending on the choice of the reaction parameter – may even be more effective than inflation forecast targeting but, at most, equally as effective as optimum inflation targeting. These three inflation-targeting strategies differ in terms of the information set used. In the case of optimum inflation targeting, the central bank's information set consists of the equilibrium nominal interest rate, the structural parameters of the model and the inflation forecast, which is derived from the reduced form: $(\rho, g^*, E\pi)$. Inflation forecast targeting uses an ad hoc reaction parameter and the inflation forecast $(\rho, g, E\pi)$. Direct inflation targeting is based on past observations[16] of the inflation rate (ρ, g, π_{-1}). Some numerical calculations will illustrate these results, where $\lambda = 2/3$ is set and the same parameter values are used as in the preceding chapter.

16 These observations may be subject to later revisions of data. Orphanides (2001) investigates the impact of data revisions on monetary policy rules.

Table 4.1: Performance of inflation targeting

Rule: $i = \rho + g(\lambda\theta\pi_{-1} + \theta\hat{\omega})$	g	Perfect foresight		Rational expectations	
		Inflation variance	Output variance	Inflation variance	Output variance
Passive policy	0	2.07	1.82	2.07	1.82
Optimum inflation targeting	3.22	0.00	2.26	0.86	2.82
Inflation forecast targeting	2.00	0.13	1.13	0.93	1.87
Direct inflation targeting	0.50	-	-	1.47	1.54
	1.00	-	-	1.19	1.53
	2.00	-	-	0.93	1.87
	3.22	-	-	0.86	2.82
	4.00	-	-	0.89	3.85
$\alpha = 0.5$, $\beta = 1.3$, $\gamma = 0.7$, $\eta = 0.2$, $\lambda = 2/3$, $\sigma_\varepsilon^2 = 1, \sigma_\upsilon^2 = 0.5, \sigma_u^2 = 2$.					

The table above gives an overview of the stabilisation results of various forms of inflation targeting. The optimum policy requires a forceful reaction to expected deviations from the inflation target. As a result, the inflation variance can be significantly reduced (or completely eliminated) compared with the passive policy. However, this is linked – especially in the case of rational expectations – with a distinctly higher variance of the output process. A reaction parameter of 2 was assumed for inflation forecast targeting.[17] This leads to a distinctly lower output variance than with the optimum policy without inflation variance being significantly increased. Direct inflation targeting is geared only to the observed inflation rate of the preceding period. Compared to a passive policy, even moderate reactions by interest rates lead to clear stability successes in inflation and output.

4.2 Price level targeting: Given optimum inflation targeting, the price level follows the process

$$p_t = p_o + t\,\hat{\pi} + \theta \sum_{j=1}^{t} (\omega_j - \hat{\omega}_j) \tag{4.15}$$

[17] Given the selected parameter values, $2\lambda\theta$ roughly corresponds to the value 1.5 frequently used in the analysis of Taylor rules. The optimum reaction to deviations from the inflation target in the preceding period is, by contrast, $3.22\,\lambda\theta = 2.47$.

The unexpected inflation shocks accumulate in the price level. This results in the variance of the price level becoming ever greater: $\sigma^2_{p_t} = t\,\sigma^2_\pi$. The price level is not determined in the long term. As an alternative to inflation targeting, the literature therefore discusses the targeting of the price level.[18] Assume that the loss function of the central bank is:

(4.16) $$L = E(p-\hat{p})^2 \equiv E((p-\hat{p})_{-1} + \pi)^2$$

This produces the reaction function:

(4.17) $$i = \rho + \frac{1}{\psi\theta}(\lambda\theta\pi_{-1} + \theta\hat{\omega}) + \frac{1}{\psi\theta}(p-\hat{p})_{-1}$$

This rule differs from the optimum rule for inflation targeting (4.7) in the last term. Price level targeting requires the central bank to react to past deviations from the price level target with the same intensity as to expected deviations from the implied inflation target. With price level targeting, the following process results for the inflation rate:

(4.18) $$\pi = \theta(\omega - \hat{\omega}) - (p-\hat{p})_{-1}$$

If the central bank pursues the strategy of price level targeting from the period t = 1 onwards,

(4.19) $$\begin{aligned} \pi_1 &= \theta(\omega_1 - \hat{\omega}_1) \\ \pi_t &= \theta(\omega_t - \hat{\omega}_t) - \pi_{t-1} \quad , \; t = 2,3,.... \end{aligned}$$

is obtained for the inflation rates. On the assumption that the shocks are not autocorrelated, the variance of the inflation rates under price level targeting thus becomes:

(4.20) $$\begin{aligned} \sigma^2_\pi &= \theta^2 E(\omega - \hat{\omega})^2 \\ \sigma^2_{\pi_t} &= 2\sigma^2_\pi \quad ; \qquad t = 2,3,... \end{aligned}$$

Apart from the first period, the variance of the inflation process under price-level targeting is twice as large as in inflation targeting. In price level targeting, the price level follows the process

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[18] See Svensson (1999b) and the literature cited there.

(4.21) $$p_t = p_o + t\,\hat{\pi} + \theta(\omega_t - \hat{\omega}_t)$$

i.e. there is no accumulation of the shocks. The variance of the price level is thus

(4.22) $$\sigma_p^2 = \theta^2 E(\omega - \hat{\omega})^2 = \sigma_\pi^2$$

Price level targeting thus 'buys' the long-term stabilisation of the price level with a variance of the inflation rates that is twice as high. With the chosen parametrisation of the model, there is also a considerable increase in the variance of the output process. Table 4.2 compares the two strategies for the case of rational expectations $(\hat{\omega} = 0)$.

Table 4.2: Inflation targeting versus price level targeting

	Inflation variance	Price level variance	Output variance
Inflation targeting	0.86	$\rightarrow \infty$	2.82
Price level targeting	1.72	0.86	12.39
Parameters as in Table 4.1; $\hat{\omega} = 0$.			

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4.3 Taylor rule, monetary targeting and two-pillar strategy: So far, only strategies that are oriented to one target have been considered. More general strategies may be derived from the loss function

(4.23) $$L = E(\pi^2 + \Phi_y\, y^2 + \Phi_\mu\, \mu^2 + \Phi_i\,(i - \rho)^2)$$

The first two terms take account of deviations from the inflation and output target that are usually contained in monetary policy reaction functions. The third term captures deviations from the monetary target. Even if rates of monetary growth are regarded as an intermediate objective and not as the final objective of monetary policy, the incorporation of this term into the loss function may be justified by the fact that inflation, in the long run, is a monetary phenomenon and that the central bank cannot be indifferent to the rates of monetary growth. With the last term, interest-rate fluctuations are sanctioned. The existence of such a term in the loss function can explain why central banks make graduated interest-rate changes (interest-rate smoothing). This term results in the reaction to the target variables being generally more subdued. (For $\Phi_i \rightarrow \infty$ the passive policy (interest rate peg) is obtained as a special case.) The optimum rule which follows from such an approach is complex and difficult to communicate to the general public. In practice, therefore, preference is often given to simple and transparent rules.

The Taylor rule is a strategy in which the central bank is oriented both to inflation and to output. To derive the optimum Taylor rule, the loss function

(4.24) $$L = E(\pi^2 + \frac{1}{3} y^2)$$

is assumed, i.e. the weight of the output target amounts to one-third of the weight of the inflation target.

Monetary growth targeting was regarded by the Bundesbank as an intermediate targeting strategy for controlling inflation. The Bundesbank had the statutory mandate to support the economic policy of the Federal Government and thus "to keep an eye" on other targets. In a wider target system, in which the targeting of inflation is indeed a priority but not the sole objective, a strategy of monetary targeting can be quite prudent, especially as such a strategy is easily intelligible and can be easily verified by the general public. In the following analysis, the monetary targeting strategy is geared solely to deviations of the monetary growth from the monetary target, i.e. $L = E(\mu^2)$.

In the two-pillar strategy, the European Central Bank sets both a reference value for monetary growth and an inflation target. In formal terms, such a strategy may be derived from the loss function $L = E(\mu^2 + \pi^2)$, with the same weight accorded to each of the two targets. In this formulation, the two-pillar strategy is a combination of monetary and inflation targeting. On the one hand, it stresses the importance of the money stock for the propagation of inflationary processes and, on the other, expresses the primary objective of stable prices.

All the cited strategies result in optimum reaction functions for interest rates, which may be expressed as follows:

(4.25) $$i = \rho + (g_\pi \pi_{-1} + g_q q_{-1}) + (g_\upsilon \hat{\upsilon} + g_\varepsilon \hat{\varepsilon} + g_u \hat{u})$$

The rules differ in the intensity with which interest rates react to past information (π_{-1}, q_{-1}) and expected shocks $(\hat{\upsilon}, \hat{\varepsilon}, \hat{u})$. Table 4.3 shows the optimum reaction coefficients.

Table 4.3: Reaction coefficients of optimum strategies

Reaction to ...	π_{-1}	q_{-1}	$\hat{\upsilon}$	$\hat{\varepsilon}$	$\hat{u}$
Inflation targeting	2.47	0.00	3.70	0.96	0.74
Taylor rule	1.34	0.00	2.01	1.44	0.40
Monetary targeting	0.68	-0.54	1.02	0.96	0.74
Two-pillar strategy	0.73	-0.52	1.09	0.96	0.74
Parameters as in Table 4.1.					

Inflation targeting reacts sharply to observed deviations from the inflation target and to expected price shocks. The reaction to output and money demand shocks is moderate. The optimum Taylor rule requires, with a coefficient of 1.34, a reaction to observed deviations from the inflation target which is close to the value of 1.5 common in the literature. The rule involves a weaker reaction by central bank rates to observed deviations from the inflation target and to expected inflation and money demand shocks than does inflation targeting. The optimum reaction to goods demand shocks is, by contrast, stronger than in inflation targeting. Monetary targeting implies an even weaker reaction to observed deviations from the inflation target and to expected price and goods demand shocks than does the Taylor rule. The reaction to money demand shocks, on the other hand, is greater. Furthermore, this rule implies a negative reaction by interest rates to the lagged price gap. This is due to the fact that the monetary growth depends negatively on the lagged price gap. It is notable that the optimum reaction coefficients of the two-pillar strategy scarcely differ from those of the monetary targeting strategy.

Table 4.4 shows what stabilisation results emerge with these rules in the case of the variables inflation, output, monetary growth and interest rates, assuming that the central bank possesses no information on the level of the shocks $(\hat{\omega}=0)$. For comparative purposes, the table contains two benchmark strategies. These are, first, the passive policy and, second, a kind of meta-strategy resulting from the loss function

(4.23‘) $$L = E(\pi^2 + 0.5\,y^2 + 0.25\mu^2 + 0.25(i-\rho)^2)$$

This loss function assigns the highest priority to the inflation target, followed by the output target, the monetary target and the objective of stable interest rates.

Orientation solely to the inflation target leads to fluctuations of all the others variables being significantly greater than in the case of a passive policy. The inflation variance is halved, but the output variance is doubled and the variance of monetary growth rises between three or four times. Additionally, there are considerable interest-rate fluctuations.

With a slightly higher inflation variance, the Taylor rule results in considerably smaller fluctuations in the other variables. The monetary targeting strategy and the two-pillar strategy differ from the Taylor rule by a halving of the variance of monetary growth, whereas the fluctuations of inflation and output are greater.

Table 4.4: Variance with alternative strategies

	Variance			
	Inflation	Output	Monetary growth	Interest rates
Passive policy	*2.07*	*1.82*	*12.25*	*0.00*
Inflation targeting	0.86	2.82	42.35	5.22
Taylor rule	0.97	1.75	20.05	1.76
Monetary targeting	2.48	2.59	8.82	1.65
Two-pillar strategy	2.25	2.44	8.86	1.60
Meta-strategy	*1.61*	*1.77*	*9.77*	*0.69*

Parameters as in Table 4.1; $\hat{\omega} = 0$

In Table 4.5, the features of the various strategies are summarised using the loss function (4.23‘). In order to be able to assess the value of information on future shocks, both cases - perfect foresight and rational expectations - are included. Given perfect foresight, the range between both benchmark strategies is quite large. Even so, inflation targeting is an exception in this context and records a loss that is greater than in the case of passive policy. The Taylor rule performs considerably better. Nevertheless, the Taylor rule is itself surpassed by both the monetary targeting strategy and the two-pillar strategy. This is due to the fact that monetary growth is a "statistic" in which money demand shocks, output shocks and price shocks are reflected. Both these strategies achieve a result which comes quite close to that of the meta-strategy.

Table 4.5: Performance of alternative strategies

	Perfect foresight	Rational expectations
Passive policy	*3.02*	*3.02*
Inflation targeting	4.80	7.08
Taylor rule	1.65	3.65
Monetary targeting strategy	0.94	3.20
Two-pillar strategy	0.95	3.04
Meta-strategy	*0.72*	*2.55*

Parameters as in Table 4.1.Calculated with loss function at 4.23‘.

If the central bank does not have or does not use any information on future shocks, i.e. if it operates under rational expectations, the leeway between the passive policy and the meta-strategy becomes very tight. Given the selected parametrisation of the model, none of the studied strategies succeeds in surpassing the passive policy solely on the basis of past information. The monetary targeting strategy and the two-pillar strategy perform better than the Taylor rule, however, and much better than inflation targeting.

4.4 Monetary targeting as an intermediate target strategy

Hitherto it has been assumed that, when fixing the interest rates, the central bank knows either the realisations of the shocks (perfect foresight) or that it assumes their means (rational expectations). Below, it is assumed that the central bank knows the monetary growth rates before it fixes the interest rates, but that it does not have any information on the realisations of the other endogenous variables. The reduced form for the deviations of the monetary growth rates from the monetary target is given in equation (4.5). Owing to (4.5), the central bank can prepare a conditional forecast for the deviation from the monetary target:

$$\tilde{\mu} = (1+\alpha\beta)\lambda\theta\pi_{-1} - q_{-1} + w \tag{4.26}$$

In other words, the central bank is in a position to observe the linear combination $w = \theta\omega + \beta\theta\varpi + u$, but not the individual shocks. If the central bank fixes interest rates in accordance with

$$i = \rho + \frac{1}{\Theta}\tilde{\mu} \tag{4.27}$$

where $\Theta = \Xi + \theta\psi$, it can then completely eliminate the deviations from the monetary target.

Is this monetary growth rule perhaps even prudent if the central bank is interested only in stabilising the inflation rates or possesses the Taylor loss function (4.24)? In actual fact, the monetary growth rule (4.27) may be superior to these strategies if the central bank observes w before it fixes the interest rates. The variance of the endogenous variables from Table 4.4 is reproduced in the first two lines of Table 4.6. The last column gives the minimised value of the loss function (4.24). The third line shows the performance of the monetary growth rule (4.27). This rule stabilises inflation and output better than inflation targeting or the Taylor rule do. It may thus be prudent to use the available information on monetary growth (i.e. a given linear combination of the output/price/money demand shocks) and pursue a monetary growth rule as an intermediate target.

Table 4.6: Monetary targeting as an intermediate target strategy

	Variance				Loss*
	Inflation	Output	Monetary growth	Interest rates	
Inflation targeting Given rational expectations	0.86	2.82	42.35	5.22	1.80
Taylor rule Given rational expectations	0.97	1.75	20.05	1.76	1.56
Monetary targeting given information on monetary growth	0.53	0.87	0.00	3.70	0.82

Parameters as in Table 4.1. ** Loss function (4.24)*

5. Summary and conclusions

This paper analyses the price gap as an indicator for the development of inflation, incorporates it into a small monetary macro-model – the P-star model – and investigates various monetary policy rules in the context of this model.

On the basis of a long-run money demand function, three indicators of inflationary pressure are discussed: the monetary overhang, the price gap and the nominal money gap. The price gap is a comprehensive indicator of inflationary pressure, which combines information on the goods market (output gap) and the money market (liquidity gap) and which can play a major role in explaining inflation dynamics as part of an extended Phillips relationship.

Although inflation is widely regarded as a monetary phenomenon, the money stock does not play an active role in the monetary transmission process in the nowadays widespread Neo-Keynesian Taylor-type models. Monetary policy impulses have an impact on the development of inflation solely through real demand and output gap. In the P-star model, monetary policy impulses act on inflation dynamics via both real demand of goods and the supply of liquidity. In this model, the central bank's interest rate policy is more effectively in a position to stabilise inflation and output, and a policy of disinflation entails fewer output losses. The empirical evidence available so far for the euro area supports the existence of a stable long-term money demand and the relevance of the price gap for explaining the development of inflation.

In an analysis of alternative monetary policy strategies in the context of the P-star model, a number of variants of inflation targeting and a strategy of price-level targeting are first considered. As becomes apparent, price level targeting does reduce uncertainty about the long-term development of the general price level. This is, however, associated with a doubling of the inflation variance and considerably greater fluctuations in the output gap.

Inflation targeting is a strategy which is geared solely to stabilising the inflation rates. If the central bank has a target system in which other variables – such as output, the money stock and interest rates – play a role alongside the inflation rate, more broadly based strategies, such as the Taylor rule, monetary targeting or a two-pillar strategy are superior to inflation targeting. The assumptions about the information set underlying the interest-rate policy play an important role in how the various rules perform. Given certain information assumptions, for example, monetary targeting as an intermediate targeting strategy may be superior to inflation targeting or to a Taylor rule, even if the central bank's loss function is only geared to stabilising inflation or inflation and output.

ANNEX A: The price gap as part of an indicator system for monetary policy

The P-star approach links disequilibria on the goods and money markets to form an indicator of the potential for inflation. The equilibrium price level and the price gap can also provide information on other markets, such as the labour market and the foreign currency market, for example, and can be applied in structural analyses. The latter fact is illustrated by the example of the breakdown of the general government balance into a structural and a cyclical component.

Table A1: Equilibrium quantities and prices

	Quantity	Price
Money market	M	(v*)
Goods market	y*	p*
Labour market	b*	w*
Forex market	-	e*

LABOUR MARKET: The starting point is labour's share in national income $\lambda = w + b - p - y$ (logarithmic), where W designates the wage rate (per employed person or per hour worked per employee), B employment, P the general price level and Y output. The equilibrium wage is expressed by $w^* = \lambda^* + p^* + y^* - b^*$. This gives the wage gap $w^* - w = (\lambda^* - \lambda) + (p^* - p) - (y - y^*) + (b - b^*)$. Owing to (2.7), this expression may also be written as

$$w^* - w = (\lambda^* - \lambda) + (v^* - v) + (b - b^*) \tag{A.1}$$

Upward pressure on wages is to be expected if labour's share of national income is lower than in long-run equilibrium (distribution pressure), if cash holdings are higher than in equilibrium (liquidity pressure) or if overemployment prevails (employment pressure). According to this concept, wage pressure arises not only with overemployment but also if there are distribution conflicts or excess liquidity.

FOREIGN EXCXHANGE MARKET: The starting point for an indicator of the foreign exchange market is the real exchange rate $q = e + p_f - p$, with P_f denoting the price level abroad, E the exchange rate (units of the domestic currency per unit of the foreign currency) and P the domestic price level. The equilibrium exchange rate as the relative price of two currencies is then expressed by $e^* = q^* + p^* - p_f^*$. The exchange-rate gap corresponds to the relative price gap, adjusted for deviations from the real exchange rate:

(A.2) $$e^* - e = (p^* - p) - (p_f^* - p_f) + (q^* - q)$$

A positive exchange-rate gap, i.e. pressure to depreciate on the domestic currency, arises if the domestic price gap is larger than the price gap abroad (relative price pressure) or if the real exchange rate is below its equilibrium level: in other words, if the domestic currency is overvalued in real terms.

BUDGET DEFICIT: If primary government spending (excluding interest expenditure) is denoted by A, government receipts by S, the deficit by D = A-S and the nominal national product by P Y, the deficit ratio d = D / PY may be approximated as follows: $d = (a - s)\theta$, where θ = A / PY is the general government spending ratio. Primary government spending is regarded as a positive function of the general price level, the real social product and the unemployment rate:

(A.3) $$a = \alpha p + \beta y + \gamma un + \upsilon_a$$

The unemployment rate (un) is explicitly included, since a major part of the government's transfer expenditure depends on the employment situation. Shocks on the level of government expenditure are represented by the disturbance term υ_a. The expenditure elasticities (α, β, γ) can be estimated by regression. A similar relationship is set up for government receipts:

(A.4) $$s = \delta(p + y) + \upsilon_s$$

Since tax law is based on nominal variables, there is no need here to differentiate between the elasticities. If, in (A.3) and (A.4), the variables are substituted by their equilibrium values (p*, y*, un*) and the residual terms by their means (zero), the structural budget deficit may be expressed as $d^* = \theta(\beta - \delta)\, y^* + \theta\gamma\, un^* + \theta(\alpha - \delta)\, p^*$. The difference between the current and the structural deficit ratio, i.e. the cyclical component and the residual component of the budget deficit, is then the sum of the following factors:

(A.5) $$d - d^* = -\theta(\delta - \beta)(y - y^*) - \theta\gamma(b - b^*) + \theta(\delta - \alpha)(p^* - p) + \theta(\upsilon_a - \upsilon_s)$$

In this equation, un* - un has been approximated by b – b*. If one assumes that the elasticity of the tax system if greater than that of the expenditure system ($\delta > \alpha, \beta$), there results an overshooting of the structural deficit (d > d*) if the capacities are underutilised, if employment is low, if prices are below their equilibrium level or if a positive expenditure shock or a negative income shock occurs. The deviations from the structural budget deficit are linked to the goods market, the labour market and the money market, whereas traditional approaches mostly take account only of the output gap and the unemployment ratio (Ziebarth 1995, Mohr 2001). The table below provides a summary.

Table A2: Disequilibrium concepts

	Capacity pressure (y-y*)	**Liquidity pressure (v*-v)**	**Employment pressure (b - b*)**	**Other determinants**
Price gap (p*-p)				
Wage gap (w*-w)				Distribution pressure
Exchange rate gap (e*-e)				Price gap abroad, real exchange rate gap
Deficit gap (d-d*)				Expenditure minus income shocks

ANNEX B: On the fiscal theory of the price level

Recently, the explanation of prices as a monetary phenomenon has been challenged by the fiscal theory of the price level (FTP)[19], according to which the price level is determined by the valuation equation for the nominal public debt (B):

(B.1) $$\frac{B_{t-1}}{P_t} = E_t \sum_{j=0}^{\infty} \delta_{t,t+j} s_{t+j}$$

In (B.1), $\delta_{t,t+j}$ is a stochastic discount factor and s_{t+j} denotes the real budget surpluses (including seigniorage) without interest payments. The right-hand side of (B.1) is the expected cash value of future budget surpluses. The valuation of public debt (B) is thus performed in the same way as the valuation of private enterprises' shares.

Notwithstanding their differing appearance, the quantity theory and the FTP are not mutually incompatible, but may be regarded as alternative ways of presenting a single theory. If Y and V, for the sake of simplification, are regarded as exogenous and constant, the quantity theory

(B.2) $$M_t V = P_t Y$$

holds. The public sector (government and central bank) determines the level of public debt, the quantity of money in circulation and the budget balance: $\{B_t, M_t, s_t\}$. This immediately produces the following problem: (B.1) and (B.2) are two equations with only one unknown, P_t. It follows from this that fiscal policy $\{B, s\}$ and monetary policy $\{M\}$ have to be *coordinated* in order to determine the price level (Sargent, 1986). Since both relationships must hold in equilibrium, equilibria exist only for restricted sets of processes for $\{B_t, M_t, s_t\}$. In a *fiscally dominated regime,* the government makes the "first move," fixes $\{s_t\}$ and $\{B_t\}$, and determines the price level via B.1. The central bank accommodates this policy by providing the required quantity of money.[20] In a *monetarily dominated regime*, the central bank controls the money stock $\{M_t\}$ and thus determines the price level. The government adjusts its surpluses $\{s_t\}$ in such a way that B.1 is met. In

19 Christiano and Fitzgerald (2000) as well as Carlstrom and Fuerst (2000) discuss the FTP in detail.

20 Cochrane (2000) shows for a cash-in-advance model that the valuation equation (B.1) alone can determine the price level, even if no money demand exists, i.e. for $V \to \infty$.

reality, there is not necessarily a sharp distinction between the two regimes.[21] If the central bank is *independent* and committed to the objective of price stability as in European monetary union, however, the monetary regime predominates and the FTP becomes less relevant in determining the price level, especially as the national fiscal policies are embedded in the Stability Pact.

21 Sargent and Wallace (1981) study a fiscally dominated regime in which the central bank can exercise a certain control over the path of the price level by having the choice between "inflation now" and "inflation later". In this "unpleasant monetary arithmetic" regime, the government fixes the primary surpluses, but does not attempt to compensate the receipts from money creation (seigniorage).

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