Development and application of DSGE models for the German economy

During the past few years, dynamic stochastic general equilibrium (DSGE) models have become an increasingly important part of the analytical toolbox used by central banks and other economic policymaking institutions. The strength of these models lies in a rigorous microeconomic foundation of dynamic macroeconomic relationships. It is thus possible, for instance, to analyse the impact of economic policy intervention, taking into account forward-looking expectations. This article begins with an introduction to the basic structure of DSGE models. It then presents a baseline model for the German economy and describes a number of model extensions that reflect specific features of the German economy. Furthermore, two specific applications are presented to show how such models can be used in monetary policy analysis. On the one hand, this article illustrates the importance of expectations consistent with stability for macroeconomic developments and warranting price stability. On the other hand, it analyses some of the monetary policy implications of the various causes of an oil price increase.

Introduction

Central bank models

For central banks, macroeconomic models play an important role in monetary and economic policy analysis. There are two major areas in which they are used: the forecasting

of aggregate economic developments and, through simulations, to help improve the assessment of the effects of certain events such as a change in oil prices or in monetary policy measures.

Central banks regularly use a variety of models for this purpose. The fact that they do not rely on just a single model or class of model allows them to utilise the specific advantages of each of the various approaches. An additional advantage in using alternative models is that different perspectives can be better brought to light, making monetary policy decisions overall more robust.

DSGE models with far-reaching implications for an understanding of stabilisation policy

In this context, "dynamic stochastic general equilibrium" (DSGE) models have recently been playing an increasingly important role. The defining feature of this class of model is a rigorous microeconomic foundation of macroeconomic relationships. This reflects the advances made in economics over the past few decades and incorporates criticisms of traditional macroeconomic modelling approaches. Among other things, such models fully and consistently reflect the fact that agents in the economy base their actions to a large extent on expectations about the future – a factor that is not incorporated (or incorporated only to a limited extent) in traditional models. This aspect, in turn, has far-reaching consequences for economic policy analysis and our current understanding of how monetary policy works. Shifts in policy can cause changes in behaviour and alter parameters once assumed to be constant.[1] Insights derived from the past are then inadequate for correctly assessing the future implications of current economic policy measures. Therefore, neglecting forward-looking expectation formation in part of the economic policy debate has produced the misconception that higher employment in the long term might be achieved with higher inflation. However, the rising inflation expectations in the 1970s, along with increases in both inflation and unemployment, proved that such a trade-off does not exist. Rather, the experience of that decade illustrates how important it is for central banks to anchor expectations in a manner that is consistent with macroeconomic stability. DSGE models are ideal for the analysis of such relationships, since their underlying rationale is that monetary policy does not consist of a series of isolated individual measures but, to a very large extent, in the effective management of expectations by means of transparent and credible strategy as the core of rule-based behaviour.

Nevertheless, the aspects addressed here – even in their simplest form – result in very complex model relationships. This argues in favour of confining models to their essentials and including in each respective model only those aspects which are germane to the specific issue under investigation.

One instrument of analysis among others

One of the implications, however, is that the actual development of macroeconomic variables, which are subject to very diverse influences, can be captured only imperfectly by such models. Especially in forecasting, this drawback can outweigh the advantage of a

1 See, for example, R Lucas (1976), Econometric policy evaluation: A critique, Carnegie-Rochester Conference Series on Public Policy 1, pp 19-46.

good theoretical basis. Accordingly, when preparing macroeconomic projections at the Bundesbank, preference is given to applying methods that are principally geared to incorporating not only economic considerations but also, to a greater degree, the statistical properties of the times series to be forecast.[2] A further limitation of the current generation of DSGE models lies in the fact that, so far, they have not been entirely successful in modelling important relationships between the real sector and events in the financial sector. This shortcoming was obvious even before the financial market turbulence of the past few months. Although this applies equally to traditional macroeconomic models, it does make clear that a central bank cannot afford to eschew a broad-ranging approach to analysis.

DSGE models: some important basic elements

Microeconomic foundations

DSGE models feature a number of key characteristics. One prime characteristic of such models is the rigorous consideration of the principle that the development of the economy as a whole is the result of the actions of its individual decision-makers. For this reason, the macroeconomic relationships are derived from well-founded microeconomic behavioural equations. With regard to the decision-makers, a distinction is generally made at least between households, enterprises, central banks, and government as the institution which levies taxes and finances expenditure. Depending on the specific matter being studied, such a model can then be expanded to include other actors, ie, banks or foreign economies, for example.

Of households it is assumed that they take decisions on their consumption, their savings, and their labour supply in order to maximise their individual utility throughout their lifetime. Firms produce within the boundaries set by their "technological possibilities" and employ labour and capital goods so as to maximise their profit throughout the period observed. The central bank is usually assumed to desire to keep the rate of inflation close to a target value – in the case of the ECB, for example, below but close to 2% – and to attempt to reduce fluctuations in overall capacity utilisation.[3]

One direct implication of this explicitly intertemporal aspect of decision-making behaviour is that current decisions depend on expectations about future developments. Accordingly, households' saving behaviour and firms' investment behaviour hinge on current and expected rates of interest. Expected inflation and costs are among the factors determining the price-setting behaviour of firms that cannot or do not wish to change their prices at will. It is only such frictions in enterprises' price-setting behaviour that make it possible to model certain empirical regular-

2 For a description of a more traditional macroeconomic Bundesbank model, see Deutsche Bundesbank (2000), Macro-Econometric Multi-Country Model: MEMMOD.
3 This requires the central bank to estimate potential output. In DSGE models, this is understood as the endogenous level of output that would be produced without rigidities, say, in price formation. This concept should therefore not be confused with the more customary notion, where potential output is measured as a trend series around which actual output fluctuates.

ities, especially of the monetary transmission process.

Rational expectations

A second major characteristic of DSGE models is the coherent formulation of the interaction between the individual decision-makers and the economy as a whole. Not only does the macroeconomic equality between supply and demand have to be observed; it also has to be ensured that the developments expected by households and firms are consistent with their current and future planned decisions. In other words, it is assumed that expectations are "rational". For this reason, firms and households also form expectations about the central bank's future behaviour. Therefore, the effectiveness of monetary policy depends less on a current decision by the central bank and more on influencing the expectation of the future behaviour of the central bank. Likewise, a central bank that wishes to make the correct monetary policy decisions not only has to pay heed to today's underlying conditions but also has to keep an eye on expected future developments. From these apparently simple assumptions, however, there follow complex interactions between the actions and expectations of all the decision-makers. If the decisions and plans of the individual agents are compatible with the macroeconomic conditions, then this is termed general equilibrium. A long-term, equilibrium growth path of an economy can be derived from a model which takes accounts of the principles described above. The complexity of the interactions, moreover, also explains why the degree of detail of current DSGE model fails to match that of traditional macro models. The strength of the DSGE approach lies not so much in a detailed modelling of the economy as a whole as in a stringent and consistent modelling of dynamic relationships between the most important macroeconomic variables without resorting to *ad hoc* assumptions.

The significance of shocks

The basic idea of these models is that the cyclical dynamics of the economy are produced by various unexpected disturbances (stochastic shocks). They explain changes in the behaviour of the individual decision-makers or in the "environmental" conditions that cannot be explained (deterministically) by the structure of the model. Examples of such shocks include changes in household saving behaviour (preference shocks), unexpected improvements in enterprises' productivity or an unexpected change in the global economic setting. Temporary and unexpected effects of this kind cause macroeconomic variables to deviate from their steady-state values. Taking account of all these elements has led to the term "dynamic stochastic general equilibrium models".

Model and empirics

Before a model developed in accordance with these principles can be used for economic policy analysis or forecasting, it has to be able to adequately replicate important empirical observations. Only then can it be used to reliably analyse the specific, relevant economic variables and relationships. Since the model's solution has a time series structure, ie, the endogenous variables depend on lagged values of the variables themselves, on other model variables and on the shocks, the model's dynamic behaviour can be compared with that of corresponding empirical time series. The

outcome, however, hinges on the economic relationships incorporated into the model – external trade links, for example. Additionally, the parameter values used to model households' and firms' decisions determine how the model's variables behave. Accordingly, the parameter values are chosen in such a way that the model's response to shocks matches the data as closely as possible. Calibration techniques or econometric estimation methods are available for this purpose. Both methods are applied at the Bundesbank depending on the question being analysed, with Bayesian methodology being used for the estimations.[4]

DSGE models for the German economy

Modular principle

Several variants of a DSGE model have been developed at the Bundesbank, which supplement the baseline DSGE model where appropriate. This "modular approach" serves the purpose of having the model employed to be most suitable for the question at hand, without making it unnecessarily complicated. Given the already complex nature of such models, which is due to the large number of different interactions described above, focusing on the essentials helps make the models more "manageable" and the results easier to interpret.

This section begins by introducing the baseline DSGE model. Its structure is similar to models now also used for economic policy analysis by other central banks, governments and international institutions.[5] Apart from the basic elements mentioned above, this applies to the inclusion of various types of market frictions and inertia in the adjustment to a new equilibrium, which are described in more detail below. Such elements have proved to be necessary so that the empirically observed relationships and actual developments of the time series can be better replicated with the DSGE models. Lagged adjustments are especially necessary in order to be able to give a realistic description of the observed behaviour of prices, consumption and investment. In the models used at the Bundesbank, the parameter values are chosen such that the model can replicate the crucial relationships of the German economy.

After the baseline model, the extensions that are particularly important for certain analyses of the German economy will be presented. A relevant factor here is that Germany is the largest economy in the euro area and is also highly integrated into the global economy. This is followed by a brief account of the main special features of the German labour market and financial system.

The baseline DSGE model

Households

The baseline model consists of a series of equations which, along with some identities, derive from the optimality conditions of households and firms and which describe the behaviour of the central bank and of fiscal

4 Detailed accounts of these methods may be found, for example, in S An und F Schorfheide (2007), Bayesian analysis of DSGE models, Econometric Reviews, 26(2-4), pp 113-172.
5 See, for example, F Smets and R Wouters (2003), An estimated dynamic stochastic general equilibrium model of the euro area, Journal of the European Economic Association 1, pp 1123-75.

The baseline model

This section explains the central steady-state relationships of the baseline DSGE model expressed in log-linear form. The ^ symbol above a variable indicates that this is a percentage deviation from the steady state. Changes in nominal interest rate and inflation are shown in percentage points.[1]

Households
Households make decisions about consumption $\hat{C}$ and labour supply $\hat{N}$. Household decisions can be summarised as

$$\hat{C}_t = E_t(\hat{C}_{t+1}) - h(\hat{C}_t - \hat{C}_{t-1}) - \frac{1-h}{\sigma}(i_t - E_t(\hat{\pi}_{t+1})) - \frac{1-h}{\sigma}(E_t(\varepsilon^c_{t+1}) - \varepsilon^c_t) \quad (1)$$

$$\mu\hat{N}_t = \hat{W}_t - \hat{P}_t - \sigma\hat{C}_t + \varepsilon^n_t \quad (2)$$

Equation (1) is the Consumption Euler equation. In equation (2) labour supply depends on the real wage $\hat{W}_t - \hat{P}_t$ and the marginal utility of consumption $-\sigma\hat{C}_t$ in which $\hat{W}_t$ represents nominal wages and $\hat{P}_t$ represents the price level.

The parameter $\sigma > 0$ determines the marginal utility of consumption and $1/\mu > 0$ represents the elasticity of labour supply while ε^c and ε^n show the consumption and labour supply preference shocks. The parameter $h > 0$ stands for the extent to which today's consumption is dependent on yesterday's level and is referred to in the literature as a habit parameter.

Firms
Each firm produces a heterogeneous good for which it has market power and can, therefore, set the price. The resulting marginal costs $\hat{\varphi}$ can be described by the following equation

$$\hat{\varphi}_t = \alpha(\hat{r}^K_t) + (1-\alpha)(\hat{W}_t - \hat{P}_t) - \hat{A}_t \quad (3)$$

The parameter $\alpha > 0$ represents the share of capital in production. The marginal costs increase with real wages and are higher the greater the cost of borrowing capital $\hat{r}^K_t$ and the lower the productivity $\hat{A}_t$.

Firms set prices optimally as a mark-up over marginal costs and take into account that prices cannot be completely adjusted to the optimal level each period. Capital stock is defined as

$$\hat{K}_t = (1-\delta)\hat{K}_{t-1} + \delta\hat{I}_t + \varepsilon^I_t \quad (4)$$

The rate of depreciation for capital $\hat{K}_t$ is $\delta > 0$. Capital formation depends on investment $\hat{I}_t$ and can be disturbed by a shock ε^I_t. Investment is defined as

$$\hat{I}_t = \hat{I}_{t-1} + \frac{1}{\Psi}(\hat{Q}_t + \varepsilon^I_t) \quad (5)$$

Investment today, $\hat{I}_t$, depends on investment adjustment costs $\Psi > 0$ and on the shadow price of investment $\hat{Q}_t$, which relates the value of investment activity today to that of investment tomorrow

$$\hat{Q}_t = \frac{r^K}{r^K + 1 - \delta} E_t(\hat{r}^K_{t+1}) + \beta(1-\delta)E_t(\hat{Q}_{t+1}) + E_t(\hat{\Lambda}_{t+1}) \quad (6)$$

The parameter β represents households' subjective time preference rate while the variable $\hat{\Lambda}_{t+1}$ represents the stochastic discount factor.

In the economy, each good is produced using labour and capital as factors of production

$$\hat{Y}_t = \hat{A}_t + \alpha\hat{K}_t + (1-\alpha)\hat{N}_t \quad (7)$$

The higher the productivity $\hat{A}_t$, the higher the output level $\hat{Y}_t$.

Macroeconomic supply of and demand for goods
The aggregated supply of goods corresponds to the total of consumption and investment demand plus public expenditure $\hat{G}_t$

$$\hat{Y}_t = c\hat{C}_t + \iota\hat{I}_t + g\hat{G}_t \quad (8)$$

The parameters c, ι and g are steady-state values.

Inflation dynamics
Aggregate inflation dynamics derive from firms' price-setting behaviour. The inflation rate is given by a Phillips curve

$$\hat{\pi}_t = \beta E_t(\hat{\pi}_{t+1}) + \kappa\hat{\varphi}_t + \varepsilon^\pi_t \quad (9)$$

The parameter κ gives the elasticity of inflation to marginal costs. Inflation can also be driven by a cost-induced inflation shock ε^π_t.

Monetary and fiscal policy
Monetary policy is described by an interest rate rule

$$i_t = \rho i_{t-1} + (1-\rho)(\phi_\pi\hat{\pi}_t + \phi_x x_t) + \varepsilon^i_t \quad (10)$$

This implies that the central bank wants to stabilise inflation and deviations from long-term potential output x_t without causing interest rates to fluctuate excessively. Parameter ρ describes the degree of interest rate variation. If the economy overheats, leading to $\hat{\pi}_t > 0$ and $x_t > 0$, the central bank will raise the nominal interest rate. The extent to which the interest rate increases is dependent on the interest rate response coefficients of inflation $\phi_\pi > 1$ and of the output gap $\phi_x > 0$. In its most straightforward form, fiscal policy can be defined by

$$\hat{G}_t = \hat{T}_t + m(\hat{M}_t - \hat{M}_{t-1} - \hat{P}_t) \quad (11)$$

The government finances its expenditure $\hat{G}_t$ from taxes $\hat{T}_t$ and the central bank profit $(\hat{M}_t - \hat{M}_{t-1}) - \hat{P}_t$ with $\hat{M}$ representing the money stock and m a steady-state value.

Model simulation
The way in which the model described above works can be illustrated with a simulation. Here we assume that the economy

1 For a detailed description of the model, see M Hoffmann, M Krause and V Lewis (2008), An estimated DSGE model for the German economy, Deutsche Bundesbank Research Centre, Discussion Paper (forthcoming).

described above is perturbed by a preference shock ε^c, causing households to move consumption to the present. (Increased consumption during a FIFA World Cup or the Olympics may serve as a case in point.) In this model simulation, we assume that the preference shock follows a first-order autoregressive process to represent the persistence in the data

$\varepsilon_t^c = \rho^c \varepsilon_{t-1}^c + u_t^c$, with $u_t^c \sim N(0, \sigma_u^2)$

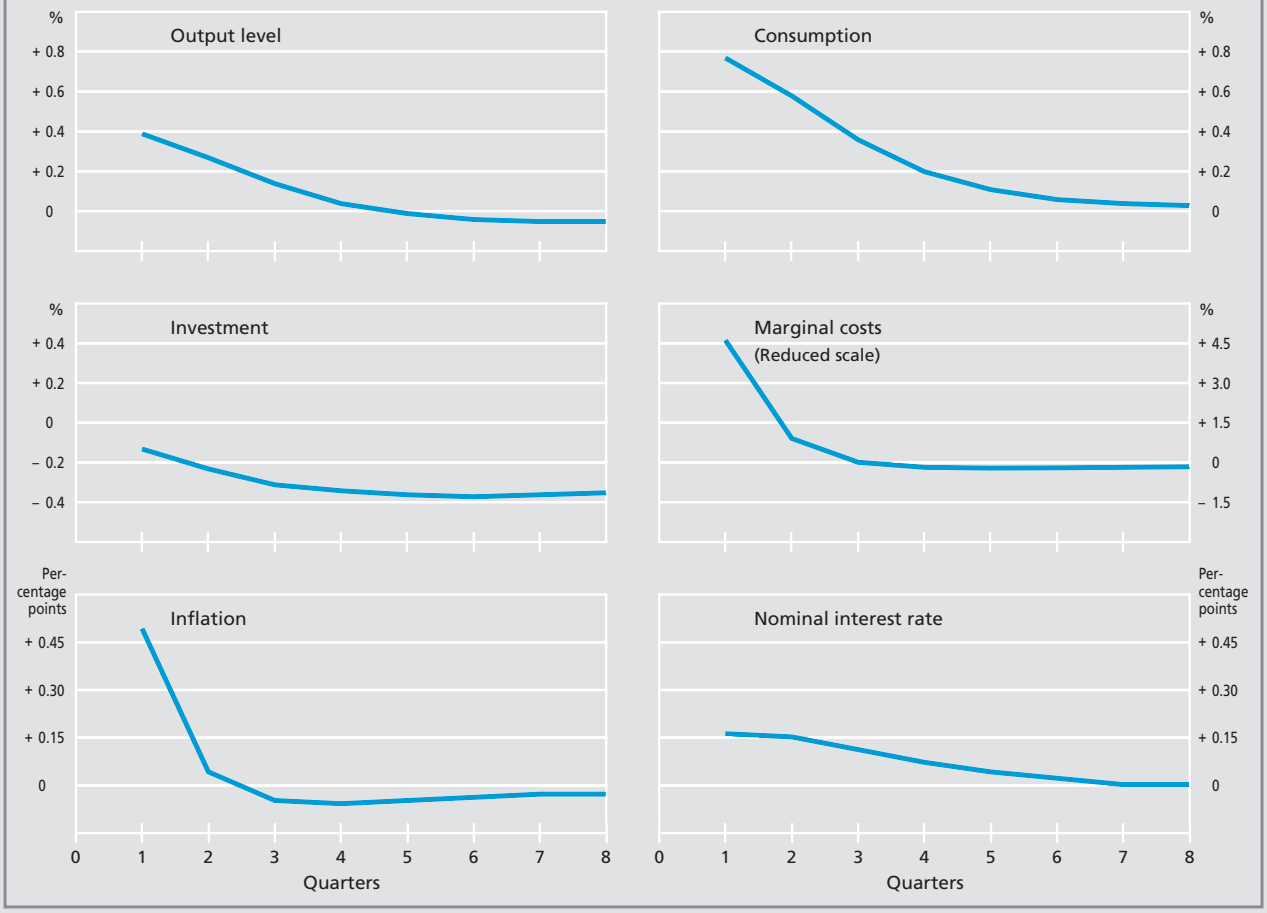
The values listed below, produced by estimating a model for German data, are used to simulate the preference shock.

$\sigma = 1.39$	$\mu = 1.91$	$h = 0.71$	$\alpha = 0.19$	$\delta = 0.025$
$\Psi = 5.48$	$\kappa = 0.09$	$\rho = 0.81$	$\phi_\pi = 2.02$	$\phi_x = 0.10$
$\rho^c = 0.20$	$\sigma_u = 0.20$	$\beta = 0.99$	$r^K = 0.035$	

The impulse response functions in the diagrams below illustrate how the economy adjusts.

They show how the disturbance causes each variable to move away from its steady state (zero line) and how it reverts back to it. Consumption rises and savings fall. The latter leads to a reduction in investment. Greater demand for consumer goods induces firms to increase their demand for labour and capital. The increased factor demand leads to an increase in marginal costs. The Phillips curve relationship shows that inflation rises. The central bank responds to rising inflation by increasing the nominal interest rate in order to increase the real interest rate.

Response of selected variables to a preference shock



policy (for details, see the explanatory notes on pages 36 and 37). Households are mainly described by their consumption behaviour and their labour supply (see equations (1) and (2) in the explanatory notes). In line with the principles set out above, consumption in the current period (in the empirical implementation, each period is set equal to one calendar quarter) depends negatively on the real rate of interest, ie, the nominal interest rate minus the expected inflation rate, expected consumption in the next period and a preference shock. Furthermore, it is assumed that households have a propensity not to let their consumption fluctuate too much after changes in income (the "habit persistence" hypothesis). This assumption ensures that the comparatively low level of volatility in consumption observed in the empirical time series can be captured by the model. Labour supply is determined by real wages and the marginal utility of consumption.

Enterprises

The behaviour of enterprises is characterised by price-setting behaviour as well as by the demand for labour and capital. Firms produce goods, for which they have certain market power. Therefore, this is a departure from the strict assumption of perfect competition. It follows from this that profit-maximising enterprises possess some discretion in setting prices. Firms will employ additional labour to produce their goods as long as the earnings per unit of labour do not exceed unit labour costs, which, in turn, also depend on the marginal productivity of labour. One major determinant of this productivity is the deployed capital stock; the more capital an enterprise uses, the more productive its labour is. The capital stock is determined, in turn, by investment. The lower real interest rates are relative to productivity, the more is invested. Adjustment costs in the investment process also ensure an empirically plausible, sluggish change in the capital stock (see equations (5) and (6) on page 36).

The production of goods in the economy as a whole depends on the aggregate input of labour, the capital stock and the general level of productivity in the economy. In the short term, output varies owing to unexpected shocks, say, in labour input. In the long term, output is determined by technological progress, capital input and population growth. In the baseline model, the demand for goods is determined by consumption demand, investment demand and the level of government expenditure. Price changes depend on the marginal costs of production and the expected future inflation rate. This results from firms' optimal price-setting. Enterprises that cannot or do not wish to change their prices every period because they face menu costs also take into account expected rates of inflation because their prices should not deviate too much from the general price level in the coming periods. Overall, these relationships result in a variant of the well-known Phillips curve, which provides a link between inflation and output. In contrast to the traditional Phillips curve, however, the expectation about future inflation here also influences current changes in prices. Effective central bank policy therefore depends not only on current monetary policy but also on expectations about the future monetary policy stance.

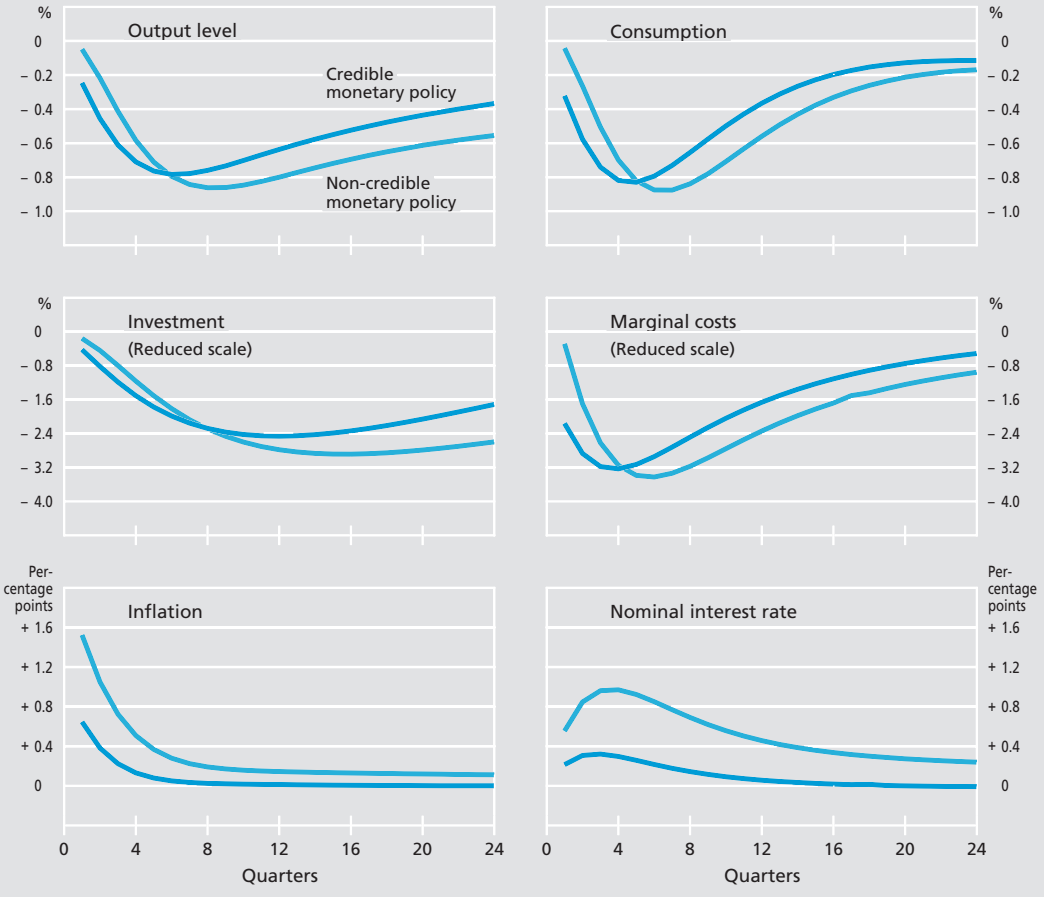
The role of expectations and central bank credibility

According to the policy rules usually applied in the monetary policy literature, a central bank responds to deviations from the inflation target. Here, two different types of response are compared. In the first scenario, the central bank is able to communicate its commitment to stability to the private sector in a credible manner. In the second, the private sector does not expect the central bank to consistently pursue its stability policy and mistakenly assumes a weaker response to inflationary pressures (thus, $\phi_\pi = 1.02$ instead of 2.02 in equation (10) on page 36). The inflation expectations thus differ systematically from subsequent actual inflation rates owing to the central bank's failure to communicate its aims in a credible manner.

The initial disturbance is assumed to be a cost-push shock, which follows a first-order autoregressive process (see chart below).

It is clear in both scenarios that the cost-push shock drives up inflation. At the same time, the nominal interest rate increases, thus counteracting the considerable price pressures. Output consequently falls below potential. By contrast, greater monetary policy credibility leads to significantly lower inflation. This is because lower inflation expectations for the future already have an impact on today's price-setting. The increase ultimately required in the nominal interest rate is therefore also markedly lower. Thus, if the central bank is able to anchor inflation expectations, inflation is lower as a result. There are also advantages for the real economy as production shortfalls are smaller and more short-lived if policy is communicated in a more credible manner. The better a central bank communicates its commitment to stability, the less volatile the response of the economy as a whole to shocks and the easier it is to ensure price stability.

Response of selected variables to a cost-push shock



Deutsche Bundesbank

A predictable and credible policy facilitates such a formation of expectations.

Monetary and fiscal policy

In models of this type, it is usually assumed that the central bank's interest rate policy can be described by what is known as a Taylor rule, according to which the interest rate is positively correlated with inflation and aggregate capacity utilisation.[6] The central bank reacts such that, if inflation rises, the real rate of interest increases as well (known as the Taylor principle). The simplified model assumes that government expenditure will rise in line with economic growth.

Repeated reference has been made to how important the formation of expectations and the credibility of monetary policy are in DSGE models and what the implications are for the interaction between all economic agents. It is especially apparent, for example, that a credible central bank can better anchor inflation expectations and, therefore, the realised inflation following a price shock. In fact, the required interest rate hike can be markedly lower than in the case of a monetary policy that is geared less credibly to price stability (see the explanations on page 39).

Extensions of the baseline model

A number of important monetary and economic policy analyses can be conducted using the baseline model. However, the German economy displays special features which cannot be ignored for certain questions and which therefore require extensions to the model. These features include Germany's role in the European monetary union (EMU) and the global economy as well as the structures in the German labour market and the German financial system. The following section focuses on these factors and on how they are taken into account in an extended model.

Germany in the global economy

Germany is not a closed economy as is assumed in the baseline model. In order to take account of this fact, one model extension captures the external links of the German economy within a three-region model. The German economy (region 1) and the other member states (region 2) form the EMU. Both regions are linked to the rest of the global economy (region 3). Depending on the focus of analysis, the rest of the global economy can mean the industrial countries outside monetary union, the emerging market economies as a bloc, or the world economy as a whole with the exception of the euro area. Depending on the interpretation, relevant parameters of the model need to be varied.

With regard to monetary union, it is important to note, first of all, that monetary policy is designed to suit European conditions rather than German ones. In the model, the interest

6 Such a rule can be derived from the perception that central banks wish to prevent or, at least, minimise deviations in inflation from the inflation target and keep actual output close to "potential output". Potential output is an important point of reference for monetary policy since output cannot deviate from potential in the long term without generating either inflationary or deflationary pressure. In this perception, if a central bank wished to realise the inflation target at every point in time, interest rate policymakers would overreact to every deviation from the target. If it seeks to return inflation to the target path more gradually after a shock, the response will be less strong. Allowing for all the simplification required by such models, this analysis addresses major aspects of the tasks and objectives of the ECB, which aims for an inflation rate below but close to 2%.

rate rule is modified accordingly. The central bank now focuses on price stability in the monetary union as a whole. However, in this context, the German situation is accorded major importance.

Within an integrated global economy, firms do not just produce goods for the domestic market; they also export part of their output. This means that firms have to decide not only a domestic price but also an export price.[7] Transport costs prevent all goods from being freely tradable, however; there also exist non-tradable goods that can be consumed only within the country of production.

Finally, account must be taken of the fact that households can also invest in financial instruments from all three regions but have a certain preference for domestic assets (home bias). This form of modelling international relationships makes it possible to analyse changes in the current account positions between the three regions and to answer questions on the implications of globalisation.

Modelling the labour markets

The labour market is a second major area in which the Germany economy differs from the stylised conditions of the baseline model. In DSGE models, as explained above, employees and employers make their decisions in line with their respective deliberations on optimisation. Households consider how they can best divide their lifetime between work and leisure, always bearing in mind their desired consumption, wages, prices etc. Enterprises consider how much labour they demand. This leads to fundamental conditions of labour supply and demand as well as a given level of employment. In this sense, there is no involuntary unemployment in the baseline models, and labour is a homogenous good that can be deployed readily and universally. This abstracts from many key aspects of the labour market, however: employees and jobs are not all identical and labour markets are characterised by a large number of institutional regulations. Although these aspects are important in explaining unemployment, it is not easy to integrate them into traditional DSGE models. Thus, in principle, in an approach that takes account of the possibility of future unemployment (or future reemployment), employers have to consider this fact before they take their decisions. On the other hand, when planning in the present, enterprises have to bear in mind that, in the future, they may not always find the employees they are looking for. Incorporating all these considerations gives the models an additional dimension of complexity which has to be accommodated by suitable approaches.

In the extended model, unemployment is explained by the assumption of search fric-

7 Empirical evidence shows that firms make use of this option and charge different prices at home and abroad. A detailed discussion can be found, for example, in P Goldberg and M Knetter (1997), Goods prices and exchange rates: What have we learned?, Journal of Economic Literature 35, pp 1243-1272, and C Engel and J Rogers (2001), Deviations from purchasing power parity: causes and welfare costs, Journal of International Economics 55, pp 29-57. For the effects of international price discrimination on trade links and welfare, see also M Hoffmann and O Holtemöller (2008), Transmission of nominal exchange rate changes to export prices and trade flows and implications for exchange rate policy, Deutsche Bundesbank Research Centre, Discussion Paper, Series 1 (forthcoming).

tions.[8] This term is used to describe the difficulties experienced by workers and firms in finding suitable jobs and labour, respectively. This process costs time and resources and results in unemployed persons often needing a long time to find reemployment and to vacancies advertised by firms not being filled immediately. This means that there are always households, also including long-term unemployed persons, who are in search of work. In an economic upswing, unemployment will therefore fall in the model, as in reality, because firms are increasingly looking for labour and making fewer persons redundant. The converse applies in a downturn. This allows a more realistic explanation not only of fluctuations in employment but also the phenomenon of structural unemployment. This depends on various, often institutional conditions in the labour market, such as the level and period of entitlement to unemployment benefit, the general wage level and the efficiency of the job-seeking process. The negotiating power of trade unions and employers also plays a key role.

The financial system

The role of the financial sector is a third area where relationships that are key for a large number of interesting questions are overly simplified in the baseline model. The financial sector does not play an explicit role in the baseline model, in which investment is financed directly by households' savings without the involvement of financial intermediaries. In the real world, however, the financial system is a key element in the chain of the monetary policy transmission process. Changes in interest rates, which raise or lower the cost of banks' financing opportunities, are passed on to potential borrowers and, in this way, also influence their demand. In Germany, for example, bank loans are a prominent feature of corporate finance, while direct financing through the capital markets is less important than in other countries.[9]

The financial accelerator in DSGE models

In current DSGE models, it has become standard to analyse credit relationships which generally feature certain frictions in that banks have only limited information about their customers. Banks can reduce these imperfections by specialising in certain industries (financing of SMEs), enterprises (relationship banking) and, in particular, by the inclusion of collateral. The structure of the financial system has implications for the effects of shocks on the economy. The relationship banking system may help to cushion the impact of shocks, while the requirement to post collateral may amplify cyclical fluctuations.[10] The value of collateral will generally rise during an upswing, making it easier for firms to borrow more funds for investment. The result is that the upswing is reinforced by this accelerator process. In a downswing, this mechanism is reversed.

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8 For the basic principles of modern labour market theory, see C Pissarides (2000), Equilibrium Unemployment Theory, MIT Press. Search frictions are integrated into a DSGE model in M Krause and T Lubik (2007), The (ir)relevance of real wage rigidity in the New Keynesian model with search frictions, Journal of Monetary Economics 54, pp 706-727.

9 See, for example, I Chowdhury, M Hoffmann and A Schabert (2006), Inflation dynamics and the cost channel of monetary transmission, European Economic Review 50, pp 995-1016.

10 B Bernanke, M Gertler and S Gilchrist (1999), The financial accelerator in a quantitative business cycle framework, in J Taylor and M Woodford (eds), Handbook of Macroeconomics, North-Holland, Elsevier.

A better recognition of the interrelationships between the real economy and financial factors is currently one of the most pressing areas of "construction" in the ongoing development of DSGE models. That applies to all macroeconomic models and not just the DSGE approach, however. Against this background, it is essential for central banks – whose measures take place via financial markets – not to limit their view on monetary conditions because of gaps in existing models. Instead, they need to include complementary views of monetary and credit developments.

Housing market

Similar arguments apply to residential financing. Recent experience in the US as well as in some European countries has brought to attention the importance of this segment of the credit market for monetary policy and the economy. The German housing market and its customary forms of financing differ in many respects from those in other countries, however. It is therefore essential to take due account of these special features in order not to copy conclusions taken from other models that do not match the German situation. For this reason, a module allowing a more precise analysis of the housing market in Germany is also currently under development.

An application: simulating the effects of oil price rises

The dramatic overall rise in oil prices, which has been taking place for some years, poses in various respects an economic and monetary policy challenge. In particular, it is leading to direct price rises for energy products and to rising cost pressure on producers, who wish to pass at least some of this pressure on to their customers. The experience of the oil price shocks of the 1970s and early 1980s, which triggered high inflation rates and recessionary developments, is often evoked in discussions of this subject. In actual fact, however, a careful analysis of the impact of oil price rises on the German economy has to investigate the causes of such increases in more detail so that the correct conclusions for the development of the economy and for monetary policy can be drawn.

Supply shock versus demand shock

In the following simulations, two scenarios are distinguished. In the first scenario, the rise in oil prices is due to an increase in the global demand for oil. In the second scenario, it results from a global supply shortage. Oil prices over the past few years undoubtedly display some features of both scenarios. To a large extent, the first scenario describes the causes of the recent oil price increase more accurately as the endogenous outcome of the sharp growth in emerging market economies such as India and China. While it is true that supply shortages in the oil market have been of significance in the past few years, the second scenario reflects more the experience of the 1970s. Of course, neither of these scenarios should be misconstrued as an attempt to give a complete picture of oil price movements in the two historical periods. Rather, the point is to highlight in stylised form a particular aspect in which the two situations differ as well as their implications.

The analysis is based on a variant in which the basic model has been extended in two ways. First, Germany – as in the above-described extensions – is modelled as an open economy. Second, it is assumed not only that capital and labour are used in the production of goods but also that oil is needed. Furthermore, domestic households consume not only traditional domestic and foreign consumer goods but also oil. In this context, Germany takes the oil price as given since it is determined in the world markets.

The most important relationships can be characterised as follows. A decline in the global oil supply leads to a rise in the real price of oil. Consumer prices in Germany go up, with negative consequences for real disposable income. Households consume less. Enterprises react to the fall in demand by cutting back production. The higher price of oil also leads to higher marginal costs, however, and to adverse repercussions on potential output. Inflation accelerates and monetary policymakers respond by raising interest rates.

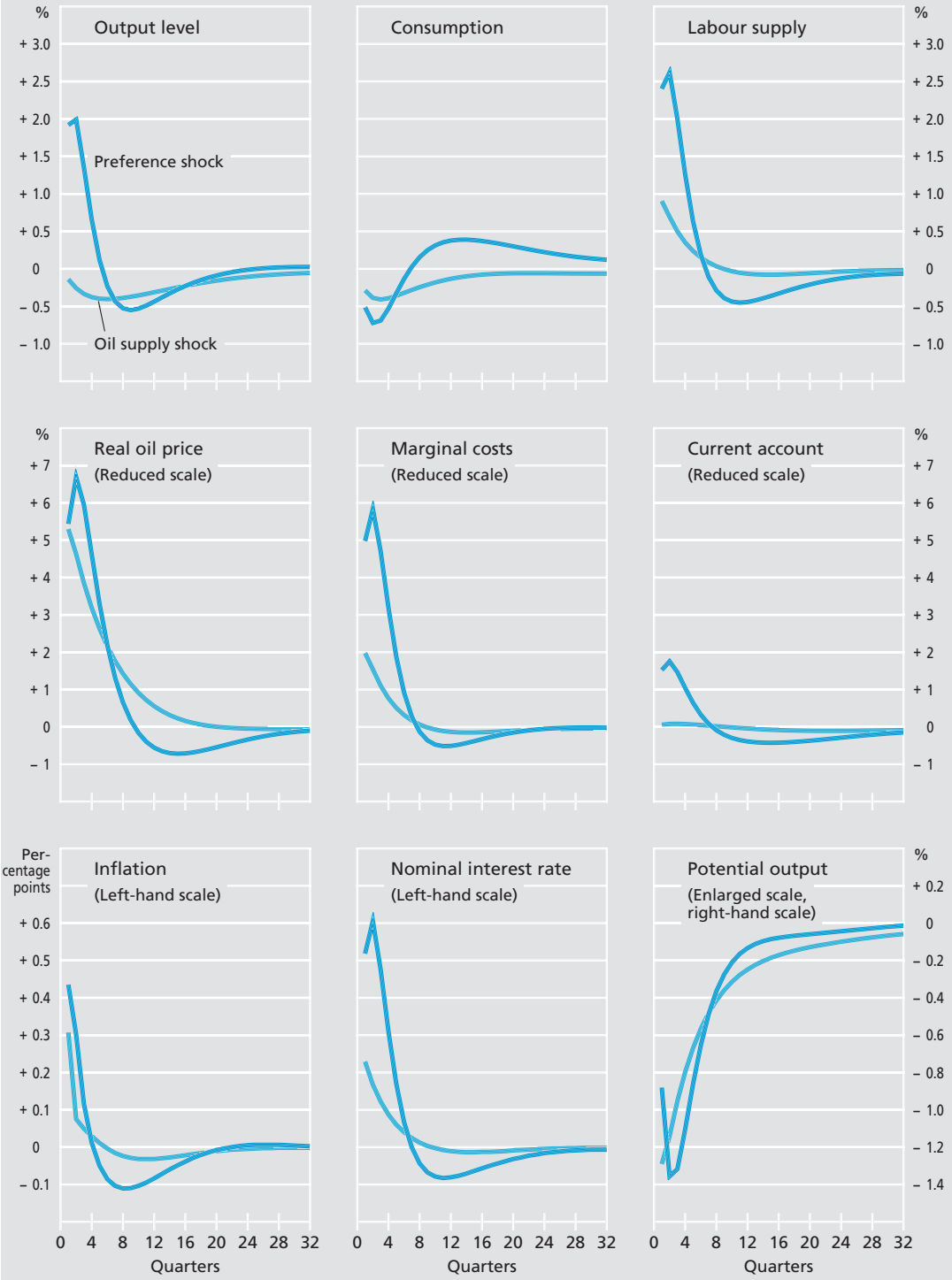
However, the rise in interest rates is markedly lower than in the case of a demand-driven increase in oil prices. As an example, a preference shock abroad leading to an expansion of foreign consumption is assumed in this scenario. Higher consumption by non-residents leads to increased output there and greater demand for oil but also to stronger demand for German products. This leads to an increase in output in Germany and a higher factor demand. There is a rise in marginal costs and, thus, in inflation. This is a clear signal to the central bank to increase interest rates – much more sharply than in the case of the oil supply shock. Households reduce their consumption, one of the reasons being that they have to pay more for oil. The overall outcome is a current account surplus. Later, however, the current account deteriorates again because households reduce their savings (see chart on page 45).

Implications for potential output and monetary policy

In spite of its simplifying abstraction, the stylised simulation experiment makes it possible to extract two aspects that, from a monetary policy perspective, deserve attention in the current situation. First, with regard to the monetary policy response to an oil price rise, it is important not to lose sight of the fact that this also has an impact on potential output. Rising oil prices will lead to a reduction in potential output, with consequences for the output gap. In other words, the effects of an energy price rise on output show up not only in the actual figures but also influence production possibilities. Monetary policymakers have to pay attention to both effects when assessing the resulting inflation risks. Furthermore, the factors driving the oil price increase are crucial in determining the appropriate monetary policy response. The more strongly demand-side influences determine the oil price increase, the smaller the adverse effects on the domestic real economy will be, and the smaller the price-dampening impact of a slowdown in the domestic economy will be as well.

What should not be overlooked, however, is the fact there are major differences in the dynamics of the oil price suggested by the model scenarios from those of actual oil price

Response of selected variables to a preference shock and an oil supply shock*



* See p 43 f for a more detailed description of the two types of shock.

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developments in the recent past. The scenarios presented here model transitory movements of real and nominal oil prices. This means that the described effects on output and potential output are necessarily temporary in nature. The effect on general inflation is likewise of limited duration. Oil prices over the past few years have been characterised by a trend increase, however. The outcome has been that energy prices have made a persistent contribution to general consumer price inflation. Similarly, this model application excludes the risk that, in such a setting, long-term inflation expectations deviate from the central bank's stability objective. The implications of such a divergence between consumers' and enterprises' expectations and the actual behaviour of the central bank have been addressed above. All in all, both scenarios tend to underestimate the current challenges for monetary policy posed by the sharp and persistent rise in commodity prices.

Outlook

DSGE models are a very promising approach to analysing macroeconomic relationships. They have specific strengths that can help precisely in economic policy decision-making. Here, as for all models and analytical instruments in general, it is true that no single model can fully capture the complexity of the real world. Besides experience and expertise, well-founded decisions taken by central banks and other economic policy decision-makers therefore depend on the use of a comprehensive analytical toolbox, in which the role of DSGE models is important and growing. Even so, there are still many questions which cannot be answered or which can be answered only tentatively at present using such models.

Possible future enhancements

The modelling of the financial systems and of their importance for economic developments has been only partly successful so far. For this reason, intensive work is being undertaken at present on how the significance of credit developments and of the monetary aggregates can be better integrated into DSGE models. Increasing attention is being paid to the fact that households and enterprises can be very different as well as to the need to focus more on this heterogeneity and its possible implications for the economy as a whole. Finally, greater consideration should be given to the fact that uncertainty still prevails about the precise structure of the economy and that expectations are not formed entirely rationally.

Nevertheless, such unresolved issues should not obscure the fact that economic policy analysis ought to be based on approaches that take into account aggregate economic relationships and, at the same time, take as their starting point the decisions of the individual agents in the product, labour and financial markets – as do the general equilibrium models presented in this article.