CENTRAL BANK OF CYPRUS
EUROSYSTEM

WORKING PAPER SERIES

# The Implementation of Scenarios using DSGE Models

Igor Vetlov, Ricardo Mourinho Félix, Laure Frey,
Tibor Hlédik, Zoltán Jakab, Niki Papadopoulou,
Lukas Reiss and Martin Schneider

December 2010

Working Paper 2010-10

**Address**
80 Kennedy Avenue
CY-1076 Nicosia, Cyprus

**Postal Address**
P. O. Box 25529
CY-1395 Nicosia, Cyprus

**E-mail**
publications@centralbank.gov.cy

**Website**
http://www.centralbank.gov.cy

**Fax**
+357 22 378153

Papers in the Working Paper Series may be downloaded from:
http://www.centralbank.gov.cy/nqcontent.cfm?a_id=5755

# The Implementation of Scenarios using DSGE Models

**Igor Vetlov, Ricardo Mourinho Félix, Laure Frey, Tibor Hlédik, Zoltán Jakab, Niki Papadopoulou, Lukas Reiss and Martin Schneider***

**December 2010**

## Abstract

The new generation of dynamic stochastic general equilibrium (DSGE) models seems particularly suited for conducting scenario analysis. These models formalise the behaviour of economic agents on the basis of explicit micro-foundations. As a result, they appear less prone to the Lucas critique than traditional macroeconometric models. DSGE models provide researchers with powerful tools, which allow for the design of a broad range of scenarios and can tackle a large range of issues, while at the same time offering an appealing structural interpretation of the scenario specification and simulation results. This paper provides illustrations of some of the modelling issues that often arise when implementing scenarios using DSGE models in the context of projection exercises or policy analysis. These issues reflect the sensitivity of DSGE model-based analysis to scenario assumptions, which in more traditional models are apparently less critical, such as, for example, scenario event anticipation and duration, as well as treatment of monetary and fiscal policy rules.

Keywords: Business fluctuations, monetary policy, fiscal policy, forecasting and simulation.
JEL Classification: E32, E52, E62, E37.

---

* Bank of Lithuania, Banco de Portugal, Banque de France, Czech National Bank, Office of the Fiscal Council Republic of Hungary, Central Bank of Cyprus, Oesterreichische Nationalbank and Oesterreichische Nationalbank, respectively. This paper was prepared under the auspices of the Eurosystem Working Group on Econometric Modelling. It benefited from comments by members of the Eurosystem Monetary Policy Committee, the Working Group on Econometric Modelling, and the Working Group on Forecasting. The authors would like to thank Günter Coenen, Antoine Devulder, Grzegorz Grabek, Michal Andrle, Karel Musil, Jiri Polansky as well as two anonymous referees for their valuable suggestions. The views expressed in this paper are those of the authors and do not necessarily reflect those of the affiliated institutions or the Eurosystem.

Correspondence: Igor Vetlov, Bank of Lithuania, Totorių 4, LT-01121 Vilnius, Lithuania. Email: ivetlov@lb.lt

# Introduction

The new generation of dynamic stochastic general equilibrium (DSGE) models seems particularly suited for conducting scenario analysis. These models formalise the behaviour of economic agents on the basis of explicit micro-foundations allowing for a distinction between intrinsic dynamics and dynamics arising from rational expectations. As a result, DSGE models appear less prone to the Lucas critique (Lucas, 1976) than traditional macroeconomic models. Yet, the use of DSGE models for scenario analysis requires making a number of choices. Scenarios can be implemented by specifying paths for a selected set of observed variables, by setting values for a subset of structural shocks or by changing certain parameter values. Moreover, the scenario event may be anticipated or unanticipated by economic agents. A choice of particular importance concerns the assumption regarding the reactions of interest and exchange rates, as economic agents' expectations about the future conduct of monetary policy shape the outcome of model-based simulations in important ways.

Practical experience of using modern DSGE models for scenario analysis in policymaking institutions is relatively limited and diverse across individual institutions. In the European System of Central Banks (ESCB) DSGE model-based analysis received large impetus as estimated DSGE models were put into use for the production of macroeconomic projections in a number of central banks. Indeed, within the ESCB there is growing evidence of a wider usage of DSGE models in preparing projections and conducting policy analysis. Scenario topics and areas of application of DSGE models are very diverse ranging from the assessment of uncertainty around the baseline projection to ad-hoc policy analysis, evaluation of structural reforms, and inputs into financial stability analysis. Still, the adoption of the DSGE approach to scenario analysis is, in many respects, an ongoing process and there is much to be learned about the design, implementation and communication of DSGE model-based scenario analysis. Consequently, the documentation on the practical implementation of these models in scenario analysis remains relatively scarce.

Against this background, this study aims at fostering the discussion of the use of DSGE models for scenario analysis. To this end, the study examines a number of conceptual issues related to the implementation of scenarios with DSGE models and presents model-based simulations aimed at illustrating these issues under alternative assumptions. A comparison of scenario implementation using DSGE and traditional models was conducted when deemed feasible. Besides fulfilling the above-mentioned objectives, this study serves to familiarise the readers with the feasibility of conducting various scenarios using DSGE models, discussing both advantages and limitations of such scenario analysis.

Section 2 presents an overview of conceptual issues relevant to DSGE model-based scenario implementation. Section 3 provides some selective illustrations of using DSGE models for scenario analysis. The focus here is on simple scenarios, which help to highlight implications of particular choices when designing scenarios using DSGE models. Firstly, we discuss implications of the assumption about shock anticipation by economic agents for the overall assessment of model reaction. Secondly, we investigate the importance of alternative treatment of interest and exchange rates for the transmission of economic shocks. Finally, we discuss issues related to the implementation of fiscal policy scenarios in DSGE models and offer some recommendations. In particular, we focus on implications of alternative assumptions regarding shock duration, the choice of fiscal instruments in specifying the fiscal policy rule, alternative treatments of monetary policy and implications of international policy coordination. The concluding part summarises the study.

# 1. Scenarios in DSGE models

This section provides an overview of conceptual issues for implementing scenarios in DSGE models, identifies key choices in designing scenarios and briefly discusses key differences of scenario implementation in DSGE and traditional macroeconometric models.

## 2.1. Scenario implementation in DSGE models: Conceptual issues

DSGE models offer the possibility of conducting counterfactual scenarios in order to assess the effects of events on the endogenous variables. The essential concept in this respect is a *structural shock*. Therefore, in what follows we start with a concise overview of the different types of structural shocks used in DSGE models, and then continue discussing how to conduct different types of counterfactual scenarios. We conclude the subsection by describing how economic policies are represented in a typical DSGE model.

### *2.1.1. Structural shocks*

Structural shocks are the ultimate source of fluctuations in DSGE models. They are structural in the sense that they are orthogonal to each other and have an economic interpretation. Structural shocks are usually modelled as an autoregressive process of order one, which is exogenous to the remainder of the model:

$$e_t = \rho e_{t-1} + (1-\rho)\overline{e} + \varepsilon_t ,$$

where $e_t$ is the *structural shock*, $\rho$ is the autoregressive parameter capturing the *shock persistence*, $\overline{e}$ is the steady-state value of the shock and $\varepsilon_t$ is the *shock innovation* (i.e. the unexpected change of the shock process).

In its log-linearized form, the shock process becomes $\hat{e}_t = \rho \hat{e}_{t-1} + \varepsilon_t$, where $\hat{e}_t$ refers to the deviation of the structural shock from its steady-state level. It is noteworthy that structural shocks are typically unobserved variables. Their historical values can be estimated using the state-space representation of the model. Hence, robustness issues (model dependence) apply to empirical estimates of the shocks.

By definition a shock (innovation to a shock) is always unanticipated[1] and, in their stochastic form, DSGE models handle only unexpected changes in shock processes. However, one can use the deterministic version of a DSGE model to analyze *anticipated* changes in exogenous processes or parameters. Thus, DSGE models in fact enable modellers to distinguish between *anticipated* and *unanticipated economic events* or shocks. From a modelling perspective, an *unanticipated shock* is a situation where an economic event is not anticipated or pre-announced. In this common case, economic

[1] It should be noted that the term "shock" is used differently in the literature. Generally, a shock refers to an unexpected or unpredictable event that affects the economy ($\varepsilon_t$ in our notation). In the DSGE literature, the term "shock" is usually used to denote the shock process $e_t$, which is driven by current and previous innovations, being, therefore, partly predictable.

agents do not react in advance; they just start reacting in the period when the shock hits the economy. On the other hand, if the event is *anticipated or pre-announced*, the agents are able to react in advance as soon as the shock is known to them. In this case the optimal behaviour is different from the one in case of an unanticipated shock. Details regarding the implementation of scenarios based on anticipated events are discussed in section 3.1.

Furthermore, DSGE models allow for the incorporation of both *transitory* and *permanent* shocks. *Transitory shocks* follow a stationary autoregressive process that does not exhibit a unit root. In other words, the autoregressive coefficient must be strictly below unity, $\rho < 1$. In this case, endogenous variables react temporarily to such a shock, but return back to the steady-state level after some time. This duration is determined by the degree of persistence of the shock and by the endogenous propagation mechanisms. Permanent shocks follow a unit root process ($\rho = 1$) implying that after a permanent shock the model variables do not return to the previous steady-state levels but converge to new steady-state levels.

As an example, the New Area-Wide Model of the euro area (**NAWM**[2]) includes a permanent labour-augmenting technology shock $z_t$ which shifts labour productivity permanently. This shock introduces a unit root process in firms' output. Since it is assumed that the shock is integrated of order one, the growth rate of the shock is stationary and evolves according to the following serially correlated process:

$$g_{z,t} = (1-\rho_{gz})g_z + \rho_{gz} g_{z,t-1} + \eta_t^{g_z},$$

where $\rho_{gz}$ is the autoregressive coefficient which is strictly below unity, $\eta_t^{g_z}$ is the shock innovation and $g_{z,t} = z_t / z_{t-1}$ represents the (gross) rate of labour-augmenting productivity growth with steady-state value $g_z$.

With a permanent technology shock, the model has to be transformed to achieve stationarity. Therefore, all variables sharing the same common real trend are scaled by the level of productivity $z_t$. When conducting a scenario, which incorporates the permanent technology shock, the original (non-stationary) variables have to be recovered by rescaling the stationarized variables by the level of the permanent technology shock.

### *2.1.2. Structural shock scenarios*

Counterfactual analysis based on direct manipulation of structural shocks is referred to as *structural shock scenarios*. The most obvious way to conduct a structural shock scenario is to set the shock innovation to a non-zero value (usually one standard deviation) in the first period and zero afterwards. The structural shock then evolves according to the AR (1) process where agents expect the shock innovations to be zero in future periods. This approach closely resembles standard impulse-response analysis.

If the modeller wishes to obtain a given path for a structural shock $e_t$, then he has to set the shock innovation in each period to $\varepsilon_t = e_t - \rho e_{t-1} - (1-\rho)\bar{e}$. This allows

[2] See Christoffel *et al.* (2008) for a documentation of the specification, estimation and properties of the NAWM.

achieving any arbitrary path for the shock process. This approach might, however, not be regarded as a fully coherent way to implement such a scenario, since it is not reasonable to assume that the economic agents would maintain their expectation of zero future shock innovations despite systematic deviations from zero in the past.

### *2.1.3. Observed variable scenarios*

Apart from structural shock scenarios, DSGE models can also be used to assess the consequences of assuming alternative paths for a subset of observed variables. Such exercises are called *observed variable scenarios*. This allows using DSGE models in conditional forecasting exercises, where forecasts of endogenous variables are conditional on a predetermined path for some other endogenous variables.

In order to be able to conduct observed variable scenarios, some (or all) shocks have to be adjusted to ensure that the conditioning information is met by the predictions. More specifically, the state-space representation of the DSGE model (which describes the solution of the forward looking model) is inverted (see Christoffel *et al.* (2007) for details). This gives the values for the subset of the structural shocks in order to keep the specified endogenous variables at their desired values over the given horizon.

The **NAWM** is used in the regular projections exercises of the ESCB under the following specification for conditioning variables:

- the nominal interest rate is assumed to follow a predetermined path over the projection horizon;
- the nominal exchange rate is assumed to be fixed at the last observed value over the projection horizon;
- foreign variables and real government consumption are assumed to take on their ex-post realisations.

In the first case the monetary policy shock is manipulated to ensure the assumed path of the interest rate. In the second case, the external risk premium shock is the one that should be manipulated to give us the pre-specified path. In the third case, all foreign shocks and the government consumption shock are manipulated.

Besides manipulating some specific shocks, an observed variable scenario can be conducted by manipulating all shocks. In this case one may set the structural shocks such that over the scenario horizon the squared distance from some alternative values for the shocks is minimized. Alternatively, following the Waggoner and Zha (1999) approach, the economic shocks can be drawn from a distribution that ensures that the conditioning information (assumption) is met. In this case, the mean of the shocks is selected such that on average it satisfies linear restrictions imposed by the conditioning assumption and the deviation of the shocks from their mean is orthogonal to the restrictions (Warne, 2008).

### *2.1.4. Parameter scenarios*

Furthermore, DSGE models can also be used to conduct *parameter scenarios*. This allows investigating the direct impact of a parameter change on endogenous variables and the impact of a parameter change on the transmission of structural shocks. Parameter scenarios can be categorized according to the degree of anticipation and duration of the simulated change as well as whether the parameter change alters the steady state of the model.

Firstly, changes in parameters can be unanticipated (e.g. a surprise change of preferences) or anticipated (e.g. a pre-announced tax or pension reform). Secondly, changes can be permanent (e.g. a permanent tax cut) or transitory (e.g. a temporary tax cut). Thirdly, parameter changes might only affect the model dynamics towards the steady state (e.g. a change of an adjustment cost parameter) or the steady state itself (e.g. a tax cut permanently affecting labour supply and/or capital accumulation, or a change in a preference parameter). In the first case one can, for example, compare the smoothed shocks for different parameter values and the same observed variables, or construct a counterfactual scenario for the observables with the smoothed shocks of one parameter vector and the transition function of another vector (Warne, 2008). In the second case, it might be interesting to look at the transition from the old steady state to the new one.

### *2.1.5. Economic policies in DSGE models*

Economic policies in DSGE models are typically described by specifying some systematic reactions of policy instruments. These reaction functions are commonly referred to as *monetary* and *fiscal policy rules*. Compared to more traditional backward-looking models, policy rules in DSGE models play a more prominent role in model simulations, mainly due to the expectations channel. First, due to their forward-looking nature, simulating DSGE models (even over a very short horizon) requires long-run stability and convergence of the model solution. In this regard, policy rules act as essential model closure rules. Second, model responses are heavily dependent on operation of policy rules as optimising forward-looking private agents take into account expected policy reactions.

The *monetary policy rule* is a device used in macro models to mimic the behaviour of the monetary policy authority, the central bank. In DSGE models the monetary policy rule is crucial to ensure price determinacy ruling out multiple equilibria (see, e.g. Lubik and Schorfheide (2004), Woodford (2003), and King (2000)). To fulfil these requirements, the monetary policy rule must be credible in the sense that all economic agents can anticipate the inflation target and the policy rate path. Usually monetary policy rules are specified in terms of systematic adjustment of the short-term interest rates to inflation and output gap. Different weights placed on these two variables capture the relative importance of inflation versus output stabilization objectives of the monetary authority. Additionally, monetary policy rules often feature an autoregressive component that accounts for the interest rate smoothening, reflecting the degree of gradualism of monetary policy.

The *fiscal rule* is a device aimed to mimic the behaviour of the government in managing fiscal policy in order to prevent debt from following an unstable path that will likely drive general government accounts to an insolvent position. Many DSGE models in academia consider balanced budget rules, which entail that the budget is balanced within each period. However, this is a very unrealistic assumption implying that governments do not maintain a debt stock. Therefore, most models used by policymaking institutions include more flexible fiscal rules, which ensure maintenance of a sustainable public debt stock and enable management of the fiscal policy through the operation of fiscal stabilisers and the implementation of fiscal packages. Typically, fiscal rules are specified in terms of an endogenous reaction of some tax rate (e.g. the labour income tax rate) to deviations of public debt (the debt gap) from its targeted level, (consistent with the debt target and the steady-state features of the economy). In some cases an indicator of the cyclical position of the economy (e.g. output gap or fiscal revenue gap) is included in the fiscal rule as well. The relative size of the parameters essentially reflects the attitude of the government towards the debt gap or the cyclical position, allowing for the specification of pro-cyclical, countercyclical or structural budget balance rules, depending on the concrete parameterisation considered.

All agents populating DSGE models are assumed to know the policy rules and believe that the policymakers will behave in line with such predefined reaction functions. Any deviations from the systematic behaviour imposed by monetary and fiscal rules will be interpreted as a *policy shock*, which cannot persist indefinitely without triggering a shift in agents' believe about policy regime (see Leeper and Zha (2003) for discussion on modesty of policy interventions). Moreover, because the stability of forward-looking DSGE models is very sensitive with respect to the operation of monetary and fiscal policy rules, conducting "no policy change" type of scenarios is only feasible over a limited time horizon, after which policy rules must be allowed to operate freely. Several practical examples illustrating the impact of an alternative treatment of monetary and fiscal policy rules are presented in sections 0.3.20.3.2 and 0.3.3.

## 2.2. Differences of scenario implementation between DSGE and traditional models

This subsection briefly discusses the key differences of scenario implementation in DSGE models and in traditional macroeconometric (TM) models. As a workhorse tool of macroeconomic analysis and forecasting employed in the majority of policymaking institutions, TM models are the predecessors of the modern DSGE models; hence, some brief comparison between the two generations of models is instructive.[3]

In comparison to DSGE models, building TM models typically rests on a partial equilibrium approach where individual blocks of a TM model can be specified and estimated independently. Therefore, model changes in TM models can be introduced more easily. This is in contrast to DSGE models, where even small changes in model structure often require re-specification of the entire model starting from the first principles. In practice, the apparent flexibility of TM models allows modellers to accommodate specific (non-standard) scenario requests relatively easy. This comparative advantage of TM models, however, comes at the cost of less stringent theoretical foundations.

[3] The theoretical foundation of a typical TM model rests on the Neoclassical-Keynesian synthesis whereby aggregate supply determines the long run and aggregate demand governs the short-run model properties. A significant share of TM model equations follows *ad hoc* specification featuring reduced-form parameters, which are typically estimated applying error-correction econometric techniques.

As regards more substantive issues, main differences in scenario implementation between TM and DSGE models predominantly stem from treatment of expectations and theoretical coherence of model structures (see Table 1 for a summary).

**Table 1. Key differences of scenario implementation in TM and DSGE models**

| | **TM Models** | **DSGE Models** |
|---|---|---|
| *Treatment of expectations* | Usually backward-looking, but can include forward-looking elements | Forward-looking |
| *Shock anticipation* | Unanticipated (backward-looking models) and anticipated (forward-looking models) | Unanticipated (default), though anticipated shocks are also feasible |
| *Shock duration* | Temporary/permanent makes no difference in backward-looking models within the scenario horizon | Anticipated duration of shock matters |
| *Structural shock scenarios* | Not feasible | Explicit manipulation of shock innovations to achieve the desired path of a structural shock |
| *Observed variable scenarios* | Manipulation of exogenous variables or residual adjustment | Implicit manipulation of shock innovations to achieve the desired path of a variable |

*Expectations and the nature of shocks*

The treatment of expectations is a major characteristic of any economic model. DSGE models typically consider rational expectations. The latter is a crucial feature in policy simulation exercises as explained in Lucas (1976). On the other hand, expectations in TM models are usually modelled as adaptive expectations, resulting in backward-looking behaviour of the model leaving these models subject to the Lucas critique and implying that simulations based on these models are flawed by a mistreatment of the formation of expectations. However, some TM models such as the Area-Wide Model (**AWM**) and **NiGEM**[4] include forward-looking behaviour of some variables, though its theoretical consistency can always be questioned due to the lack of explicit micro-foundations. Whilst in forward-looking TM models both anticipated and unanticipated shocks can be simulated, pure backward-looking models allow for unanticipated shocks only.

*Permanent versus transitory shocks*

In purely backward-looking TM models, the solution of the model requires neither linearization nor computation of the steady state. These models are typically solved recursively in levels. Therefore, within the first $t$ periods there is no difference between implementing a permanent shock or a transitory shock of duration $t$, since in those first $t$ periods both types of shocks will have the same effect. Nevertheless, beyond the first $t$ periods, those shocks will produce different results.

Introducing a permanent shock into a DSGE model may require transforming the model to achieve stationarity of the non-stationary variables, depending on the solution method. After running the simulation, the stationary results have to be transformed back to obtain the scenario result. More importantly, the forward-looking nature of DSGE

[4] NIGEM (**N**ational **I**nstitute's **G**lobal **E**conometric **M**odel) is an estimated multi-country model developed by the National Institute of Economic and Social Research (NIESR).

models implies that even the model responses in the first period depend on the duration of the shock.

*Structural shock scenarios*

Since TM models do not include structural shocks (i.e. exogenous stochastic processes featuring clear economic interpretation), it is not possible to specify a scenario in terms of structural shocks. Instead, it has to be implemented by adjusting the residuals and/or exogenous variables.

*Observed variable scenarios*

Observed variable scenarios can be implemented in both types of models. In a TM model, a desired path for an endogenous variable can be achieved by manipulating exogenous variables or by residual adjustment. In the case of residual adjustment, two steps are necessary to simulate the effects of a desired path of an endogenous variable[5] on the remainder of the model. Firstly, the residuals in the equation of that variable have to be determined[6]. This can either be done on a trial and error basis or by inverting the model (i.e. letting the model compute the set of residuals consistent with that path). Secondly, the model has to be simulated with that residual path for the desired variable. The response of the rest of the model variables would imply indirect effects on that endogenous variable. This can be avoided by dropping that variable (i.e. declaring it as exogenous and dropping the respective equation).

[5] The same procedure can be used in the case of multiple variables.

[6] In equations without residuals (e.g. the GDP definition equation), this procedure becomes slightly more complicated, since the modeller has to make decisions about which other endogenous variables have to be changed.

# 3. Practical implementation issues: Some illustrations

This section provides selective model-based simulations illustrating important aspects of DSGE implementation in scenario analysis. First, we discuss the implications of event anticipation (anticipated vs. unanticipated shocks) on model behaviour. Second, we investigate the importance of alternative treatments of short-term interest and exchange rates for the transmission of economic shocks. Lastly, we conclude the section discussing issues related to the implementation of fiscal policy scenarios using DSGE models.

## 3.1. Anticipated vs. unanticipated scenario events

The forward-looking nature of DSGE models enables modellers and policymakers to distinguish between anticipated and unanticipated events (Wohltmann and Winkler (2009), Schmitt-Grohé and Uribe (2008), and Wouter and Kaltenbrunner (2009)). A possibility to introduce nontrivial paths of anticipated events into a structural model simulation is crucial for monetary or fiscal policy analysis. In this case all agents including policymakers have an opportunity to take into account the future development and deal with the future changes with full beliefs. In reality many events can be fully or at least partly anticipated (government announcement of a future tax reform, plans of market deregulation, firms' commitments for some actions, etc.). The anticipated nature of future changes allows both private agents and policymakers to react in advance. This is especially important in an inflation-targeting regime, which is based on forward-looking behaviour of monetary policy. In this subsection we demonstrate how expectations of future events can be captured within a structural model simulation and how anticipation affects the behaviour of economic agents.

### *3.1.1. Event anticipation and dynamics of response*

In case of anticipated events the simulation horizon can be divided in an "announcement phase" until period *T* (e.g. the period when the anticipated event actually takes place) and an "implementation phase" after period *T*. If the expectations are fulfilled, there is no surprise, no new information and no "jump" in economic variables.[7] If the expectations are not fulfilled, economic variables jump and the simulation features "boom-bust" scenarios. Thus, in principle, the dynamics of the economy can be driven mainly by "news". A simple example illustrating differences of model dynamics following an anticipated and unanticipated shock is provided in Appendix A.

The reaction to an anticipated shock depends on a length of the period between the announcement and the realisation of the event or policy change. The longer the time horizon is, the higher the adaptability in behaviour of economic a/gents is, implying that the reaction to the shock does not suffer from high and frequent changes. Note that the reaction of the economy crucially depends on the dynamics, i.e. the rigidities in the

[7] In case of an anticipated shock, the smoothness of the reaction of economic variables crucially depends on the ability of all agents to revise their plans, thus smoothing the impact of the shock. However, this may not occur for all agents. For instance, liquidity-constrained households cannot engage in inter-temporal consumption smoothing since they do not hold assets.

economy. The more flexible the economy is, the shorter will be the period of necessary adjustment to an announced shock.[8] The simulation results as well as the implementation technique are different for anticipated and unanticipated shocks. There are many ways of solving models with announcements.[9] They differ mostly in the degree of user input needed and computational efficiency.

In case of *unanticipated* shocks, one of the procedures can be simply described in the following way. Model equations are transformed to the state-space representation with the assumption of a zero mean value for all shocks used in the model. After solving the model, shocks are added to the system. Indeed, the shocks are unknown until the period when they occur.

On the other hand, using *anticipated* shocks requires a slight modification of the solution approach and understanding of the final form of the solved state-space representation. All anticipated shocks are an essential part of the solution of the model. One can also incorporate additional state variables extending the state-space form and create non-trivial anticipations in all standard solution packages. The anticipated shock is dealt as a perfect foresight (belief) of agents. In this case the shock is a part of agents' optimization problems.

A mixture of anticipated and unanticipated shocks is also possible. It can improve the predictive abilities of the model, bring a new dimension to the model framework, and offer an economic story closer to prospective economic behaviour. Most importantly, the expectation shocks in a particular period may concern a very specific path of a variable – e.g. following large revisions in a foreign demand or price assumption.

A possibility to use anticipated or unanticipated shocks or their combination for simulations is, however, connected to some additional issues. For example, all agents in most of our models have the same information sets[10]. There is no assumption of information asymmetry and all agents react immediately when anticipated shocks appear (in accordance with the model structure and setting). This can cause problems because in reality some agents do not have full information, evaluate information in different manners, or simply do not want to react. Yet all these facts pertain to unanticipated shocks also. An important phase of model evaluation then becomes an impulse-response to anticipated shocks with different horizons of realisation. Therefore, it could be more convenient to treat an anticipated change as a single shock or a sequence of unanticipated shocks. In case of the combination of anticipated and unanticipated shocks, it may be hard to advocate that some shocks should be anticipated and some of them unanticipated. As an illustration, Appendix B presents an example of alternative treatment of future

[8] Technically, this means that, in contrast to the standard case where the dynamics of the model is driven by stable eigenvalues of the model, during the announcement phase the economy is driven both by stable and unstable eigenvalues of the system. The agents use the inverse of unstable dynamics to "discount" the future shocks. Classical papers by Blanchard and Kahn (1980) or Klein (2000) provide a lot of intuition in this respect compared to other solution methods, e.g. undetermined coefficients.

[9] For a detailed description of different solution methods see, e.g. Marimon and Scott (1999) or Heer and Maußner (2005).

[10] Clearly, government, central bank and public have different information sets and this may affect economic dynamics, but solving DSGE models with information heterogeneity is very complex. The problem of the information set may be, for example, the anticipation of regulated prices, government spending, or the assumption that the central bank can costlessly monitor all technology shocks, habit shocks, etc. This is certainly a strong simplification.

change in administered prices and explains why unanticipated shocks might result in better and more realistic projection compared with the option of anticipated shock.

Regarding the use of anticipated shocks it should be further noted, that most of the currently built DSGE models are estimated under the assumptions that the structural shocks are unanticipated. Therefore the reliance on anticipated shocks over the forecast horizon might not be fully consistent with the estimation methodology. The solution to this problem might be a change of the estimation methodology that could reflect the assumption of anticipated nature of some variables.[11] On the other hand, scenario analysis, compared with the regular projection exercise, provides somewhat more degrees of freedom in the treatment of anticipated vs. unanticipated shocks since it might be based on a different information set than the one available for the general public in the case of a realistic macroeconomic forecast.

### *3.1.2. Forecasting with anticipated shocks*

Using anticipated paths of exogenous shocks is very useful in forecasting exercises if these are conditioned on a path of some exogenous variables – e.g. rest of the world assumptions, commodity prices, etc. The choice between anticipated and unanticipated shocks for capturing exogenous assumptions should be addressed depending on how much of the considered information is publicly available, as well as how much it is a part of the information set that determines the general public's expectations. For those central banks that transparently reveal their forecast assumptions, the reliance on anticipated shocks is one of the natural choices. In general, however, there are no rigidly applicable rules for the use of anticipated vs. unanticipated shocks in the current forecasting practice of central banks.

As using anticipated shocks may be useful for conditioning on exogenous variables, it is absolutely crucial for conditioning on endogenous variables such as interest and/or exchange rates as done by many central banks. Scenarios using conditioning with repeated shocks are often communicated as an announced policy – which is not the case. If these scenarios are to be treated as "as if" scenarios where all agents know that policy authority is conditioning on a particular path of interest rate then conditioning using anticipated shocks must be carried out with all the consequences for the dynamics of the economy. Note that the reaction of the economy to identical paths of interest rates strongly depends on whether it is pre-announced or sequentially surprising[12]. The rigidities of the model and the distinction between "old Keynesian" and

[11] Note also that there are non-trivial econometric consequences of anticipated shocks (Hansen and Sargent (1991), and Lippi and Reichlin (1994)). Anticipated shocks may lead to non-fundamental representations of the model, where the econometrician has a different (smaller) information set than households and firms. This complicates econometric analysis, including structural VAR analysis.

[12] Given the forward-looking and "rational" nature of most DSGE models, a protracted period of surprising agents may be "immodest" in terms of Leeper and Zha (2003) and at odds with rational expectations equilibrium.

"new Keynesian" theory, including the forward-looking Fisher equation, become apparent. [13]

From the perspective of shock manipulation in forecasting practice, one can distinguish between *hard tunes* and *soft tunes* (Andrle *et al.* (2009) and Andrle (2008)). Conditioning (hard tunes) on exogenous or endogenous variables paths is easy to calculate and delivers implied structural shocks. More specifically, hard tune means that the selected variable will have a certain predetermined value in a given simulation and the corresponding shock (shocks) will be generated endogenously. It means that the value of the fixed variable is the same for all model simulations, however, the corresponding shock (or set of shocks) that is (are) consistent with that value will change from one simulation to another. Thus, hard tune resembles observed variable scenarios described above. The choice of shocks and their period of occurrence (past, current or future) matter a lot since the underlying economics is rather different then.

Setting shocks in a simulation (soft tunes) works similarly to structural shock scenarios. Soft tune means that the given variable will have some value for one (let's say baseline) simulation and the shock has always the same value for all subsequent simulations, therefore the variable of interest will not be fixed at the predetermined value in subsequent simulations.

In case of combining anticipated and unanticipated shocks the result of hard and soft tunes simulations may differ. The recommendation one may draw from the analysis is that independently of the events being announced or unanticipated, the simulation of alternative scenarios with respect to a baseline should be performed using soft tunes (without conditioning on any variables) in order to facilitate communication of the scenario.

### *3.1.3. Anticipated and unanticipated shock simulation: An example*

To illustrate the differences between anticipated and unanticipated shock simulations, we present estimates of the impact of a temporary increase of foreign prices[14] on some selected macroeconomic variables. In this particular scenario exercise we employ a DSGE model of the Czech National Bank[15]. The simulation results are displayed in Figure 1.

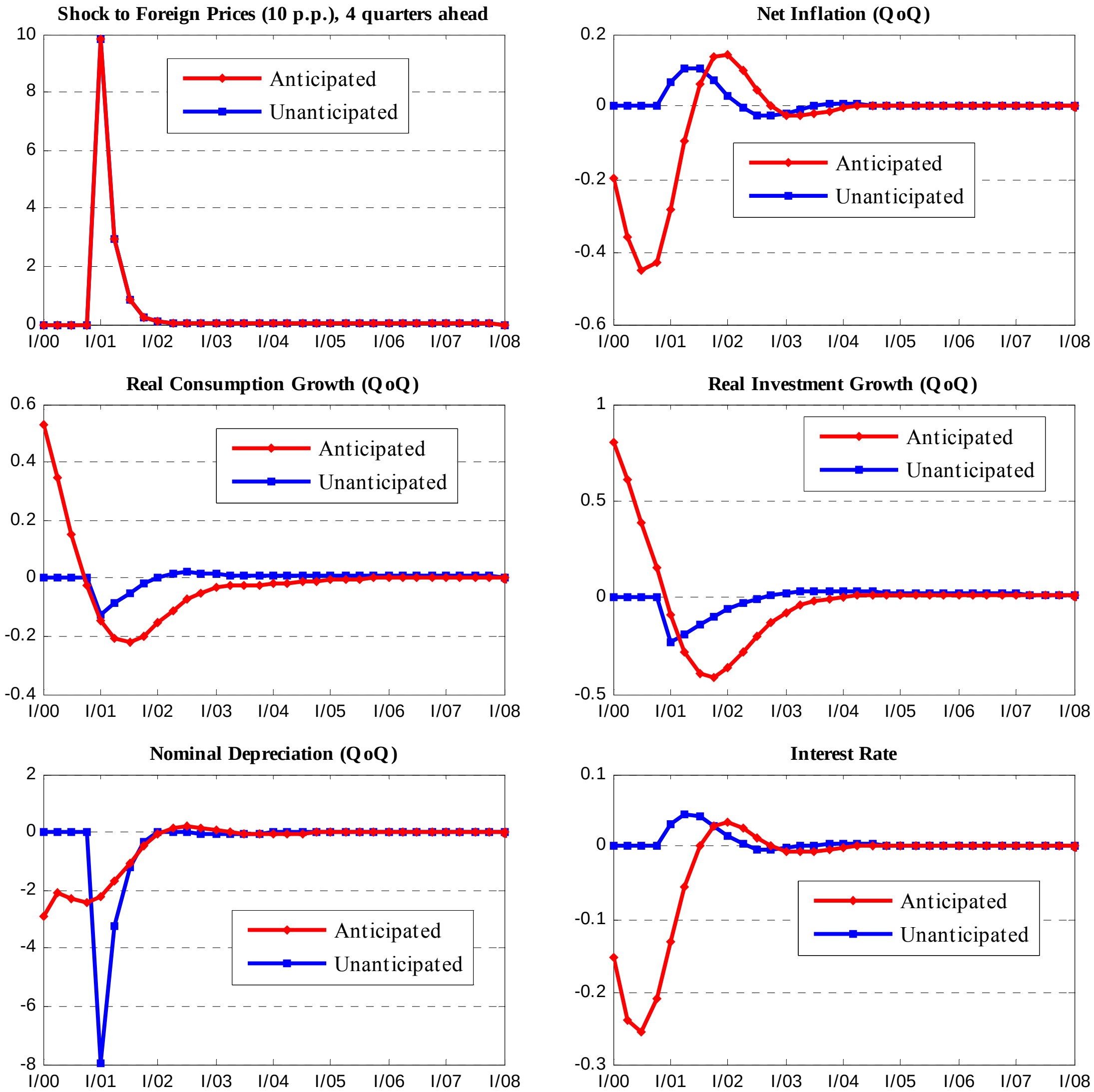
---

[13] For example, a protracted period of time (with respect to a particular model's dynamics) of high nominal interest rates may eventually and clearly lead to higher inflation as the economy and real interest rates strive to converge to equilibrium.

[14] The rationale for simulating foreign prices (or foreign interest rates or foreign demand) as anticipated shocks is quite well motivated. Many central banks rely on publicly available forecasts of foreign exogenous (exogenous, when the forecasting model is not based on a multi-country setup) variables, such as Consensus Forecast, etc. in their forecasting practice. These commercial products often reflect the anticipations of a wide range of analysts in many countries. Many institutions subsequently use these publicly available forecasts; therefore, it is plausible to assume that the shocks, replicating the assumptions about the future path of exogenous variables, are treated as anticipated.

[15] The model builds on the New-Keynesian tradition. It exhibits important nominal (wage and price and import price rigidities) and real (habit formation and investment adjustment costs) frictions in the economy enriching the real business cycle dynamics. To capture important stylized facts of the Czech economy, the model is multisectoral, including domestic and imported intermediate goods that are used for the production of final goods. The model explicitly works

**Figure 1. Macroeconomic impact of anticipated and unanticipated increases in foreign prices**




**Note:** All responses are reported as deviations from the model's baseline in %.

Higher foreign prices lead, *ceteris paribus*, to increased domestic inflation via the import price channel. In the case of the unanticipated shock, the jump in foreign prices leads to higher net inflation during the period when the shock takes place (Figure 1). In reaction to the positive foreign price inflation pressures, the central bank increases nominal (and real) interest rates, thus suppressing the main components of real GDP, such as real consumption and investment. The initial nominal exchange rate appreciation, that is fully consistent with the uncovered interest rate parity condition and the central bank's reaction function, substantially mitigates the inflationary impact of foreign prices on domestic inflation. Consequently, inflation returns back to its target through gradually

with trends in sectoral relative prices, real exchange rate appreciation, high import-intensity of exports, imperfect exchange rate pass-through, investment specific shocks and increase in trade openness. Foreign variables (GDP, interest rates and PPI) are modeled as a simple AR(1) processes.

falling import price inflation. On the whole, the economy returns back to its steady-state level relatively quickly due to falling nominal and real interest rates consistent with inflation returning back to target.

Contrary to the case where the shock is unanticipated, the possibility for agents to react to the shock in advance significantly changes the dynamic response of the presented variables. Now, agents know the timing and the magnitude of the future shock and adjust their behaviour to it from the beginning. The nominal exchange rate appreciates before the shock hits the economy (the magnitude and timing depends critically on the anticipation horizon). This anti-inflationary effect is consistent with lower inflation and interest rates. Lower real interest rates as well as prices motivate agents to increase their consumption and investment. Because foreign inflation is unchanged in the first four periods and the nominal exchange rate is appreciated, foreign inputs are cheaper for domestic residents, which, in turn motivates them to increase investment expenditures[16]. In Appendix C we show how responses to anticipated temporary foreign price shock vary with a horizon of anticipation (2, 4, and 6 quarters ahead). In particular, the initial appreciation of nominal exchange rate is higher the smaller the announcement period is.

## 3.2. Treatment of interest and exchange rates

The design of a scenario exercise often requires deciding which variables should be treated as endogenous or exogenous. In particular, in preparing macroeconomic projections, it is common practice to conduct scenario analysis where policy-relevant variables are treated as predetermined variables: government consumption, short-term interest and exchange rates. Yet, these assumptions bear important implications for model-based simulation results, as they modify the shock propagation mechanism, and, thus, may substantially alter quantitative (and possibly qualitative) results of the analysis.

The importance of alternative treatment of policy variables in DSGE models is augmented by the fact that, when making choices, private economic agents form expectations about future realization of policy variables. In other words, agents' response to shocks crucially depends on the expected course of action taken by policymakers. This section illustrates implications of alternative assumptions regarding the endogeneity of nominal interest and exchange rates for the analysis of the transmission of economic shocks.

### *3.2.1. Design of the exercise*

For the sake of expositional clarity, in what follows, we consider one typical demand-side (export preference) shock and one supply-side (domestic price mark-up) shock. We investigate the impact of these shocks on real GDP and consumer prices under alternative assumptions regarding short-term interest and exchange rates. First, we report simulation results assuming unchanged (from the baseline) paths for interest and exchange rates over the scenario horizon. Following the ECB's practice of using the **NAWM** in projection exercises, conditioning of interest and exchange rates is implemented assuming an

[16] Note that investment goods are assumed to be produced by using imported goods only.

implied sequence of unexpected innovations to the monetary policy and uncovered interest parity shocks, respectively. Second, we allow for an endogenous response in both interest and exchange rates.

Our quantitative analysis is based on the simulation results obtained using the estimated DSGE models of the ECB (**NAWM**) and the National Bank of Hungary[17]. While in both models the exchange rate dynamics is modelled in terms of a standard uncovered interest parity condition, the monetary policy rules feature some differences. In the **NAWM**, the rule is based on a systematic reaction of the short-term interest rate to deviations of domestic inflation and output growth from their respective target. In the Hungarian model, monetary authorities put zero weight on output stabilization and focus mainly on stabilizing domestic inflation and the exchange rate. We have opted to use these two models to analyse the role of monetary policy rules in economies featuring different degree of openness. As it turns out, the openness of the economy matters for the shock propagation under alternative treatment of interest and exchange rates in simulations.

In all simulations we consider transitory (one-off) unanticipated shocks only. The size of a shock (impulse) is implied by an assumed transitory unanticipated change in an observed variable. In particular, an export preference shock is calibrated consistently with a one percentage-point increase in the quarterly growth rate of real exports, whereas a price mark-up shock is calibrated consistently with a one percentage-point increase in the quarterly growth rate of the GDP deflator. In terms of timing, the shock (or rather the innovation to the shock[18]) takes place in quarter 1 and has contemporaneous effects on the rest of model variables. Starting from quarter 2 onwards the model is solved for all endogenous variables (including those directly shocked).

### *3.2.2. Discussion of the simulation results*

The key results of the exercise are summarized in Table 2. It shows the responses of annual growth rates of real GDP and of the consumption deflator (or CPI) to the export preference and the domestic price mark-up shock under alternative assumptions about nominal short-term interest and exchange rates over a five-year period. In addition, Figures 2 and 3 display impulse responses of real GDP, consumer prices, nominal interest and exchange rates in terms of percentage deviations from the model's baseline, except for the response of the interest rate, which is reported as annualised percentage-point deviation. Besides two central scenarios, in order to single out the incremental contribution of the exchange rate based adjustment mechanism, we also report simulation results of an interim step where we allow for an endogenous response of the nominal interest rate combined with a fixed path for the nominal exchange rate.

Let us start with the export preference shock simulation results for the **NAWM**. Following the shock to export demand, aggregate demand rises and induces some upward price pressures. Under endogenous policy response, the interest rate rises and dampens

[17] See Jakab and Világi (2008) for model documentation.

[18] In the case of the NAWM, the structural shocks considered in this section are specified as AR(1) processes. As regards the Hungarian model, the export preference shock is specified as an AR(1) process while the price mark-up shock follows a white-noise process.

domestic demand. Moreover, the higher domestic interest rate triggers an appreciation of the domestic currency, thus, curtailing export demand to some extent. The counteractive domestic monetary policy response also helps to reduce the surge in inflation following the shock as well as to speed up the return to equilibrium conditions. As shown in Figure 2, the flexibility of nominal exchange rate allows to achieve higher level of output combined with smaller increase in prices, i.e. endogenous exchange rate responses facilitates a more favourable output-inflation trade-off faced by policymakers.

**Table 2. Responses to export preference and domestic price mark-up shocks under alternative assumptions in the NAWM and the MNB model**

| | **Response to an export preference shock** | | | | | **Response to a domestic price mark-up shock** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1y** | **2y** | **3y** | **4y** | **5y** | **1y** | **2y** | **3y** | **4y** | **5y** |
| *Exogenous policy interest and exchange rates* | | | | | | | | | | |
| **NAWM** | | | | | | | | | | |
| Real GDP | 0.35 | 0.11 | -0.11 | -0.13 | -0.11 | -0.80 | -0.05 | 0.05 | 0.01 | 0.02 |
| Cons. deflator | 0.06 | 0.14 | 0.10 | 0.04 | -0.02 | 2.12 | 0.35 | -0.54 | -0.51 | -0.45 |
| **MNB model** | | | | | | | | | | |
| Real GDP | 0.74 | -0.48 | -0.23 | -0.02 | 0.00 | -0.36 | -0.09 | 0.10 | 0.12 | 0.10 |
| CPI | 0.05 | 0.05 | 0.01 | 0.00 | 0.00 | 1.50 | 0.28 | -0.30 | -0.38 | -0.34 |
| *Endogenous policy interest and exchange rates* | | | | | | | | | | |
| **NAWM** | | | | | | | | | | |
| Real GDP | 0.22 | 0.00 | -0.07 | -0.05 | -0.03 | -1.62 | -0.41 | 0.68 | 0.53 | 0.30 |
| Cons. deflator | 0.02 | 0.04 | 0.02 | 0.01 | 0.00 | 2.02 | 0.00 | -0.66 | -0.36 | -0.15 |
| **MNB model** | | | | | | | | | | |
| Real GDP | 0.71 | -0.47 | -0.21 | -0.01 | 0.00 | -0.63 | 0.12 | 0.26 | 0.15 | 0.07 |
| CPI | 0.04 | 0.03 | 0.00 | 0.00 | 0.00 | 1.44 | 0.14 | -0.29 | -0.25 | -0.18 |

**Note:** Impulse-responses of real GDP and GDP deflator show percentage-point deviations of annual average growth rates in the variables following the realization of the shock from their respective baseline (when no shocks occur) annual average growth rates.

Under the assumption of fixed interest and exchange rates, domestic monetary policy becomes accommodating and the adjustment-enhancing channel of competitiveness is substantially muted. In line with the monetary policy rule, private agents expect a monetary policy tightening; however, an unchanged nominal interest rate surprises them positively. As a result, the impact of the shock will be not only bigger, but also it will take longer for the economy to return to the baseline path.

As regards the impact of the shock in a much smaller and more open economy (such as the Hungarian economy) the domestic output response is very much influenced by the export preference shock and at the same time inflation is more or less cushioned (see Figure 3). This reflects the relative strength of the adjustment mechanism in the Hungarian economy based on the real exchange rate (external competitiveness) channel. Domestic monetary policy is less effective in counteracting the strong output effects, but offsets inflationary consequences. The latter, though, are less pronounced than in a more closed economy.

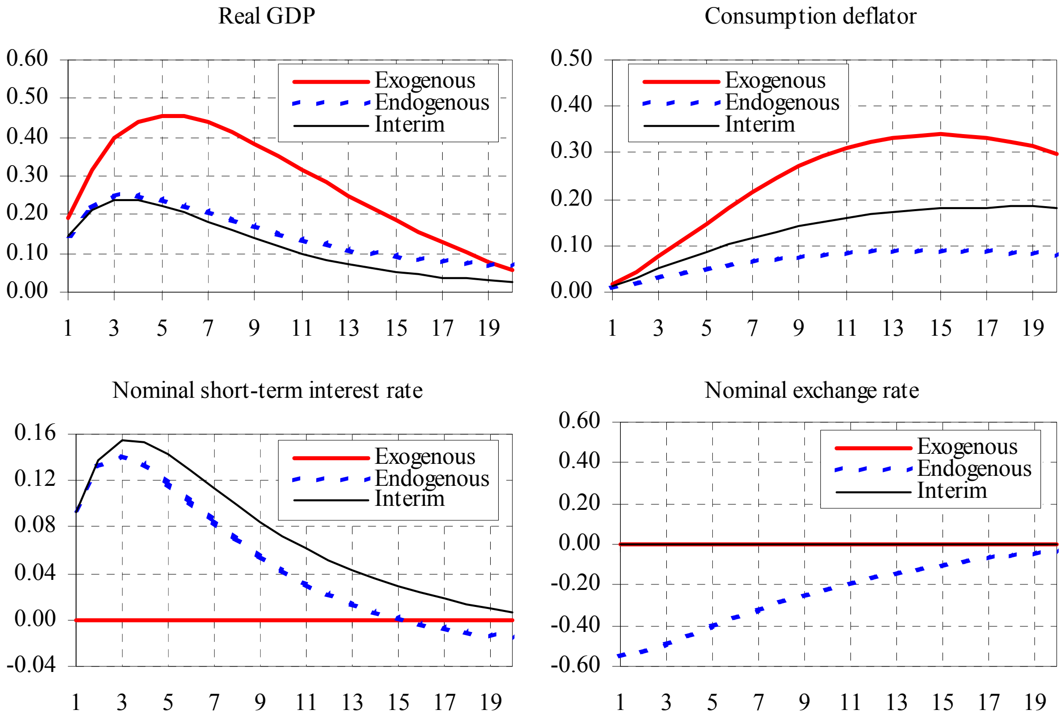
Turning to the price mark-up shock, in the **NAWM** the endogenous monetary policy response clearly implies a larger contraction of output (see Table 2). At the same time, active monetary policy produces a somewhat smaller increase in domestic inflation. The higher interest rate stimulates a reduction in domestic demand and also initially induces appreciation of the domestic currency vis-à-vis the rest of the world. The quantitative importance of the exchange rate changes for the overall transmission of the shock in the **NAWM**, however, is found to be rather negligible. Similar to the analysis of the demand–side shock discussed above, we find that active monetary policy facilitates faster macroeconomic adjustment (Figure 2).

In the Hungarian model featuring a higher degree of external openness, the major channel of transmission of monetary policy is through the nominal exchange rate (see Figure 3). Similarly to the **NAWM**, in the Hungarian model the endogenous domestic monetary policy response results in a bigger initial reduction in output as compared to the simulation under exogenous policy interest rate assumption (see Table 2). Contrary to the **NAWM**-based simulation results, allowing for endogenous response of the nominal exchange rate results in a substantially larger initial output contraction and a faster return to the baseline as compared to simulations based on the assumption of a fixed exchange rate. In terms of inflation performance, the Hungarian model-based results are similar to the corresponding results produced by the **NAWM**.

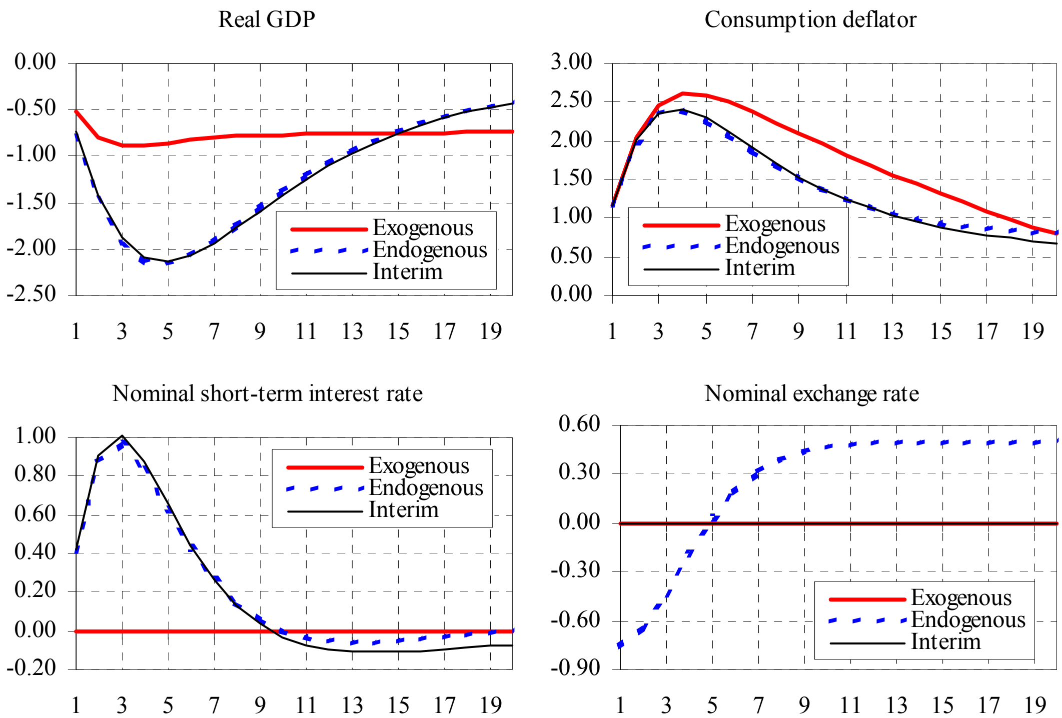
These simple simulations illustrate the non-negligible implications of alternative assumptions regarding monetary and exchange rate responses for model reactions to shocks, in particular on the speed and size of the macroeconomic adjustment. Imposition of the exogenous path for interest and exchange rates may significantly alter impulse-responses and the economic interpretation of the scenario. In case of an unanticipated exogenous path, such an assumption implies additional shocks to interest and exchange rates, since model-based expectations are not fulfilled. On the other hand, assuming an anticipated exogenous path may raise modelling issues, as the expectation formation mechanism turns inconsistent with the underlying structure of the model. In case of estimated DSGE models, such as used in this section, considering anticipated shocks is also inconsistent with respect to the model estimation strategy, which typically assumes that shocks are unanticipated. For above reasons an endogenous treatment of interest and exchange rates in model simulation exercises is advisable. Any scenarios featuring an alternative treatment of interest and exchange rates should be prudently compared against such a benchmark scenario.

**Figure 2. Responses to export preference and domestic price mark-up shocks under alternative assumptions in the NAWM, in %**

*Export preference shock*

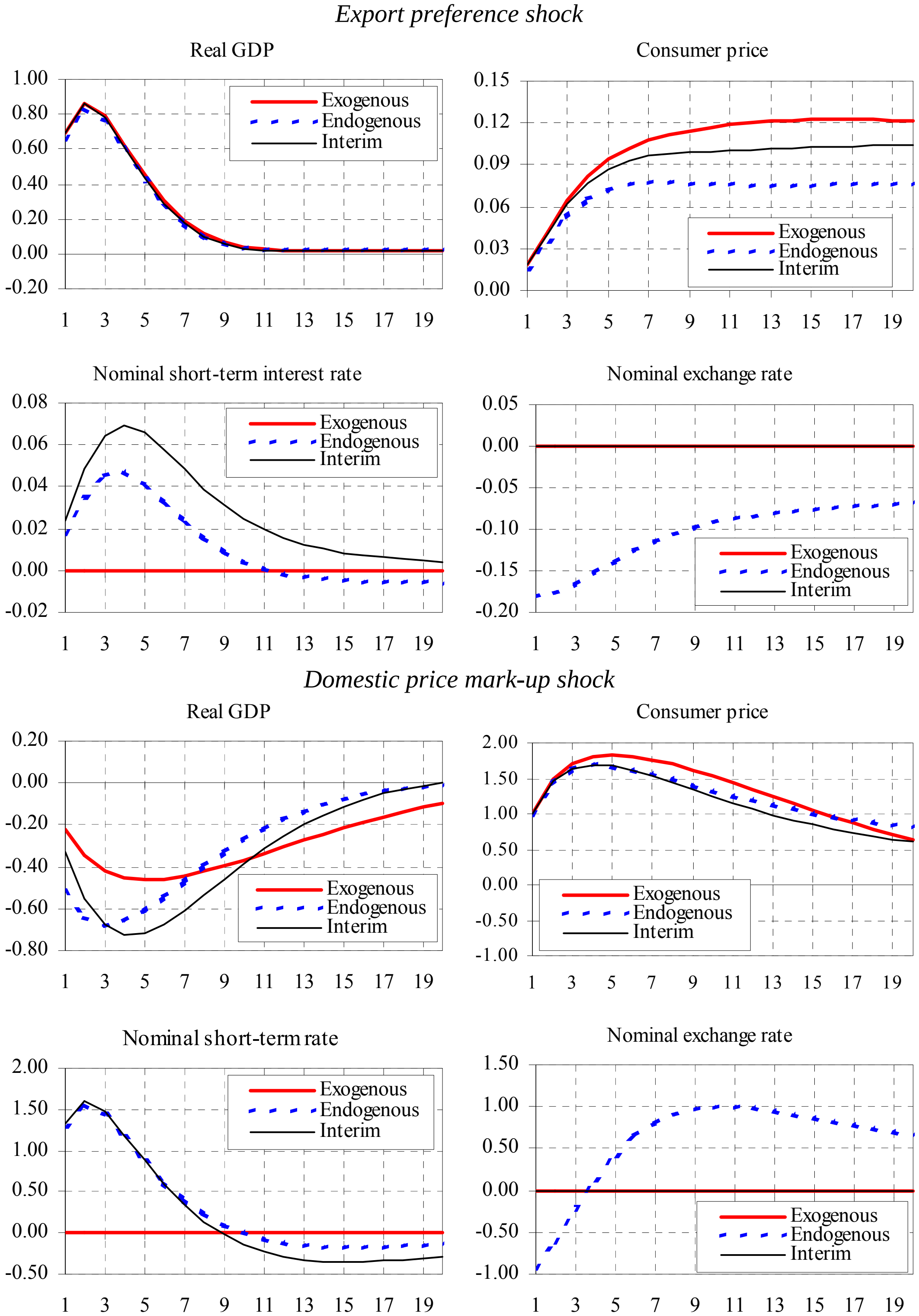



*Domestic price mark-up shock*




**Note:** Legend “Exogenous” refers to model simulations assuming a predetermined path for the nominal short-term interest and exchange rates; legend “Endogenous” denotes model simulations allowing for an endogenous response of nominal short-term interest and exchange rates; legend “Interim” refers to model simulations allowing for an endogenous response of the nominal short-term interest rate and assuming a predetermined path for nominal exchange rate. All responses are reported as percentage deviations from the model’s baseline, except for the response of the interest rate, which is reported as annualised percentage-point deviation.

**Figure 3. Responses to export preference and domestic price mark-up shocks under alternative assumptions in the Hungarian DSGE model, in %**




**Note:** Legend "Exogenous" refers to model simulations assuming a predetermined path for the nominal short-term interest and exchange rates; legend "Endogenous" denotes model simulations allowing for an endogenous response of the nominal short-term interest and exchange rates; legend "Interim" refers to model simulations allowing for an endogenous response of the nominal short-term interest rate and assuming a predetermined path for nominal exchange rate. All responses are reported as percentage deviations from the model's baseline, except for the response of the interest rate, which is reported as annualised percentage-point deviation.

## 3.3. Fiscal scenarios in DSGE models

In the current international environment, shaped by the global financial crisis and the myriad of the fiscal stimulus packages approved in many countries, the policymaking institutions[19] intensively use DSGE models to assess the impact and adequacy of the fiscal expansion. While, at the current juncture, fiscal scenarios are highly topical, in the context of our study, they can also be used to highlight numerous issues related to scenario implementation in DSGE models. In particular, this subsection illustrates the sensitivity of DSGE-based simulations with regard to the assumed duration of the fiscal shock, alternative specification of fiscal policy rules, alternative treatment of monetary policy and potential international spillover effects.

The quantitative DSGE-based analysis in this subsection is based on two DSGE models: the Banque de France multi-country model (**BdF-GIMF**) and the Banco de Portugal small-open economy model (**PESSOA**). These models share a number of features with most DSGE models currently being used; however they also entail some significant differences in the modelling of households' behaviour. In particular, **BdF-GIMF** and **PESSOA** share a number of features with the GIMF model of the IMF. These models include appealing features for fiscal policy simulations, since, thanks to the overlapping generations' structure, both liquidity constrained and non-liquidity constrained households are intrinsically non-Ricardian. The multi-country DSGE models enable a richer assessment of spillover effects and the gains from international policy coordination. In addition, in order to benchmark fiscal policy simulations and to illustrate some differences between DSGE models and more traditional macroeconometric models, we use **NiGEM**-based simulations. **NiGEM** includes a menu of options that can be tuned to make the model more similar to a DSGE model or closer to a traditional macroeconometric model. In particular, choices can be made regarding nominal rigidities, the Ricardian equivalence and households' forward-looking behaviour. **NiGEM** also features liquidity-constrained consumers (the contemporaneous elasticity of consumption to current income can always be interpreted as the proportion of disposable income held by liquidity-constrained agents). Financial markets are forward-looking, with long-run and expected short-run interest rates being linked by a yield curve equation.

The structure of this subsection is as follows: firstly, we present the central fiscal scenario results featuring a temporary fiscal expansionary shock; secondly, we analyze the implications of a permanent fiscal shock; thirdly, we investigate the role of the fiscal rule by considering its alternative specification; fourthly, the role of the monetary policy rule and implications of switching it off temporarily are discussed; fifthly, we address the implications of a coordinated increase in government consumption across the world

[19] The utilisation of general equilibrium models for the assessment of the impact of expansionary fiscal policy is quite common in the literature (Baxter and King (1993), Blanchard and Perroti (2002) and more recently Galí *et al.* (2007), Mountford and Uhlig (2008), Forni *et al.* (2009) and Corsetti *et al.* (2009)). However, the utilisation of the new generation of models in policy making institutions for regular analysis has started more recently with the Global Economy Model (GEM) and the Global Integrated Monetary and Fiscal Model (GIMF) by the IMF and a number of the DSGE models developed in many central banks (European Central Bank, Federal Reserve Board, Bank of England, Bank of Finland, Bank of Sweden and Bank of Norway, among others). See, for example, the IMF staff position note "The case for fiscal policy stimulus" by Freedman *et al.* (2009).

economy as compared to unilateral fiscal expansionary policy. Finally, we conclude and derive some practical recommendations for fiscal policy simulations using DSGE models.

### *3.3.1. The fiscal multipliers in the central scenario*

In the discussion of fiscal policy issues, the magnitude of the fiscal multipliers is a key issue. It reflects how powerful fiscal policy might be as a macroeconomic stabilisation device. In the context of the fiscal stimulus debate, the magnitude of the multiplier of each expenditure and revenue item is relevant in setting the best policy mix to achieve the degree of stimulus desired. However, there is still no consensus on the effectiveness of temporary fiscal measures. Given empirical difficulties related to estimating multipliers, short-run multipliers may vary widely according to the estimation approaches, from negative numbers to figures above unity. These differences may be explained by the degree of financing constraints faced by the country, the openness of the economy, the monetary policy response and the reaction of private agents' saving. The uncertainty on the size of fiscal multipliers is well documented in Van Brusselen (2009) (see Table 3). It is noteworthy that DSGE multipliers are generally larger than those from traditional macroeconometric models.

**Table 3. Range of fiscal multiplier estimates for the US**

| | **Narrative record models**[20] | | **VAR/SVAR models** | | **Macroecono-metric models** | | **GE/DSGE models** | |
|---|---|---|---|---|---|---|---|---|
| | **Low** | **High** | **Low** | **High** | **Low** | **High** | **Low** | **High** |
| **Public spending multipliers** | 1.0 | 1.4 | -3.77 | 3.68 | -0.6 | 1.6 | 0.0 | 3.9 |
| **Tax cut multipliers** | - | 3.0 | -4.75 | 2.64 | -0.4 | 1.3 | -2.63* | -0.23* |

**Note:** * Results for a large economy from the IMF's Global Fiscal Model.
**Source:** Van Brusselen (2009).

The fiscal blocks of the DSGE models under consideration are quite disaggregated and, therefore, allow for the simulation of expansionary fiscal policy through alternative instruments. Thus, on the revenue side, a stimulus on labour income tax, consumption tax or firms' social security payments may be considered; while on the expenditure side, one may consider a stimulus on government consumption, government investment, government transfers (targeted or untargeted). In this paper, for exposition clarity, we will focus on the results of government consumption expansion (simulations results for temporary fiscal stimulus featuring alternative instruments can be found in Appendix D).

We consider a temporary fiscal stimulus as the central scenario, consisting of an expansion of government consumption amounting to 1% of the initial steady-state GDP over a four-quarter period. We assume that the fiscal consolidation will start in the beginning of the fifth quarter and will be achieved through the full reversion of the stimulus and by the adjustment of the labour income tax to bring the government debt ratio back to its target value. Furthermore, it is assumed that both the expansionary

[20] The narrative record method attempts to discriminate between automatic and discretionary changes in spending or taxation (or both) on the basis of available historical information regarding discretionary changes in fiscal stances (Van Brusselen, 2009).

package and the consolidation strategy are announced from the outset and are fully credible.

In the central scenario the monetary policy rule operates during the whole simulation period, implying that some crowding-out effects arise from the fiscal expansion. Furthermore, we assume full credibility of fiscal stimulus, implying that the risk premium is not affected by the fiscal expansion. In the case of **PESSOA**, this implies that interest rates will remain unchanged over the simulation horizon, since they are taken as exogenous for a small-open economy participating in the euro area.

**Table 4. The impact of a temporary government consumption shock**

| | PESSOA | | | BdF-GIMF | | | NiGEM | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** |
| **CPI inflation** | 0.2 | 0.2 | -0.3 | 0.5 | 0.5 | 0.3 | 0.1 | 0.3 | 0.2 |
| **Real GDP** | 0.8 | -0.9 | -0.5 | 1.0 | -0.3 | -0.3 | 0.7 | 0.5 | 0.1 |
| ***Multiplier*** | 1.4 | - | - | 1.3 | - | - | 1.1 | - | - |
| **Fiscal balance** | -0.6 | 0.0 | 0.1 | -0.8 | -0.2 | -0.1 | -0.7 | 0.0 | 0.1 |
| **Public debt** | -0.3 | 0.7 | 0.7 | -0.2 | 0.5 | 0.5 | - | - | - |

**Notes:** The values in the table show the deviation from the baseline level in percentage point for CPI inflation, fiscal balance (as a % of GDP) and public debt (as a % of GDP). For real GDP the percentage deviation from baseline level is presented. Since the shock is defined as an increase in government consumption of 1 % of steady-state GDP, the ex-post deterioration in fiscal balance ratio tends to fall below 1 pp., due to the endogenous response of fiscal revenues. The fiscal multiplier is obtained as the ratio of the GDP deviation from steady-state per percentage point of ex-post deterioration of the fiscal balance to GDP ratio. PESSOA reports simulations for the Portuguese economy; BdF-GIMF and NiGEM show results for the euro area.

Quantitatively, we find that fiscal multipliers on government consumption are positive in the first year for all models. In the medium run as the fiscal consolidation starts and the fiscal expansion is fully reverted, the initially positive impact of fiscal expansion on real activity becomes negative in the case of the DSGE models, but not in the case of **NiGEM**[21] (see Table 4). It is noteworthy that short-run multipliers differ quite substantially across countries in both **BdF-GIMF** and **NiGEM**, being the largest in the United States (see also some country specific simulation results based on **NiGEM** in Appendix E). Manteu and Martins (2009) identify the level of openness and the degree of borrowing constraints as key determinants of the strength of the impact on GDP of the fiscal stimulus.

In the case of the **PESSOA** model, after the initial expansionary impact on economic activity, the simulation suggests a strong macroeconomic reversion. This reflects in particular the fact that in a small-open economy model, the fiscal stimulus impact on prices triggers real exchange rate appreciation, which has strong implications for the trade balance and net foreign assets inducing a sizeable negative wealth effect. Moreover, the fiscal rule imposes a rapid reversion of debt implying a substantial increase in labour income tax as soon as fiscal consolidation starts. Finally, it should be recalled that in the case of **PESSOA** interest rates are exogenous and, therefore, the reversion of the fiscal stimulus is not cushioned by an eventual monetary policy response.

[21] We do not report the impact on the euro area public debt in NiGEM simulations since there is no aggregate variable available in the model but only public debt levels of individual member countries.

In the case of **BdF-GIMF**, the fiscal rule is laxer and allows for a slower return to a balanced budget. Reversal in households' consumption after the fiscal stimulus remains very limited, as the adjustment of hours worked is weak and net exports deterioration is rather small.

In the case of **NiGEM**, financial markets operate in a forward-looking framework (bonds, equity and exchange rates) and react instantaneously to the shock, leading to some crowding-out of the impact of the increase in spending through higher interest rates and exchange rate appreciation. However, the behaviour of households is fully backward looking in the sense they react to current income and wealth and not to permanent income, which limits negative wealth effects arising from future increases in taxes.

### *3.3.2. Permanent versus temporary fiscal policy shocks*

A key issue in the simulation of fiscal policy shocks is the reversibility of the fiscal measures undertaken. In general, fiscal stimulus packages tend to be temporary, implying that the measures included must be designed so as to make them easily reversible. However, one can also use DGSE models to assess the impact of permanent fiscal shocks[22]. For instance, the assessment of a fiscal consolidation process through a programme of permanent cuts in expenditure is tantamount to a permanent fiscal policy shock.

To assess the impact of a permanent public spending expansion, we consider a permanent expansion of government consumption expenditures by 1% of initial steady-state GDP level and we compare it with the temporary shock simulation previously described (the central scenario). As in the central scenario, the fiscal rule is switched off in the first year. From the second year onwards, the fiscal rule is switched on, adjusting the labour income tax rate to bring the government debt ratio back to its target value. Contrary to what occurs in the central scenario, the increase in government consumption is not reverted to its pre-shock level. As in the case of the temporary shock, the expansionary package and the fiscal instrument, on which the fiscal rule is based, are announced from the outset and are fully credible.

The DSGE model-based simulation results in Table 5 point to a substantially different impact of a permanent government consumption expansion in comparison with the central scenario (see Table 4 for comparison). The differences between a transitory and a permanent government consumption shock are much smaller in **NiGEM** simulations.

In the case of **PESSOA**, the multiplier of a permanent shock in the first year is smaller than in the case of a temporary shock, reflecting the powerful wealth effects stemming from the permanent increase in government expenditure on households consumption path. Over the medium-run, as fiscal consolidation starts, the impact on real GDP and the multiplier becomes largely negative, not only as a result of a much stronger real exchange appreciation than in the central scenario, but mostly due to the larger

[22] It should be noted, that the permanent fiscal shock scenario described in this section corresponds to a transition between two steady states, simulated with a non-linear version of the model under perfect foresight, whereas in section 2.1.1 the discussion of a permanent shock simulation corresponds to a unit root shock simulated within a linearized version of the model under rational expectations.

increase in labour income tax rate required to finance the permanent increase in expenditure. This increase in labour income tax rate triggers a strong disincentive for households to supply labour affecting the consumption/leisure decision significantly. As a result of the higher distortion implied by the increase of the labour income tax rate, in the new steady state real wages (hours worked) will be above (below) their initial steady-state levels.

**Table 5. The impact of a permanent government consumption shock**

| | PESSOA | | | BdF-GIMF | | | NiGEM | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** |
| **CPI inflation** | 0.3 | 0.5 | 0.3 | 0.4 | 0.5 | 0.3 | 0.0 | 0.2 | 0.2 |
| **Real GDP** | 0.4 | -1.8 | -2.6 | 0.5 | -0.3 | -0.4 | 0.6 | 0.4 | 0.2 |
| ***Multiplier*** | 0.4 | - | - | 0.6 | - | - | 0.9 | - | - |
| **Fiscal balance** | -1.0 | 0.7 | 0.3 | -0.9 | -0.1 | -0.1 | -0.7 | -0.3 | -0.2 |
| **Public debt** | 0.3 | 1.0 | 0.8 | 0.1 | 0.7 | 0.7 | - | - | - |

**Notes:** See explanatory notes in Table 4.

The mechanisms leading to a smaller impact multiplier in the case of a permanent shock are quite similar in **BdF-GIMF**. First, there are no gains in private consumption in year 1 as compared to the central scenario (and there are some decreases in years 2 and 3). Second, the deterioration of the trade balance is larger due to the larger appreciation in the effective real exchange rate.

### *3.3.3. The role of fiscal rule specification*

The fiscal instrument, adjusted endogenously by the fiscal rule, is an important choice of the modeller and should reflect the most likely behaviour of the government during the consolidation period. Usually, fiscal rules adjust a specific tax rate in order to meet a specific fiscal surplus or debt ratio target. One should be aware that the choice of the instrument is likely to affect results to some extent. In what follows, we illustrate the sensitivity of model responses to alternative setting of fiscal rules in the DSGE models.[23]

To assess the impact of using alternative fiscal consolidation instruments in the rule, we consider the central scenario that features a labour income tax based consolidation and we simulate two additional scenarios in which the fiscal consolidation is based on the consumption tax and on a lump-sum tax. The results presented in Table 6 for **PESSOA** and in Table 7 for **BdF-GIMF** were obtained under the assumption of perfect credibility of the fiscal policy strategy.

Starting with the **PESSOA** model, the simulation results suggest that the fiscal consolidation instrument might affect the impact of the fiscal expansion and the magnitude of the impact multipliers. The consumption tax rule has the highest multiplier

[23] The PESSOA model includes a *structural budget balance rule*, following Kumhof and Laxton (2007). This type of rule implies a reaction that depends on the specific characteristics of the shock under consideration. In the case of permanent shocks, the fiscal instrument adjusts to ensure that the public debt stock is kept close to its target level, while in the case of temporary shocks, the debt stock may deviate sensibly from the target, accommodating most of the impact of the operation of automatic stabilisers, keeping the fiscal instrument, the labour income tax rate, broadly unchanged. As in PESSOA, the fiscal rule in BdF-GIMF aims at the long-run stabilisation of the public deficit to GDP ratio. However the business cycle stabilization component of the fiscal policy is made more explicit in BdF-GIMF, by making the public deficit contra-cyclical.

since it induces some anticipation of consumption by the non-liquidity constrained households as they are aware that the consumption tax rate and CPI inflation will increase more substantially as the fiscal consolidation starts. This not only boosts activity, but also has a favourable impact on consumption tax revenues, limiting the budget balance deterioration. The lump-sum tax based consolidation has a slightly lower multiplier, since it does not yield so much tax revenues in the first year. The central scenario has the lowest multiplier and in the medium-run is the one that implies a larger decline in GDP reflecting the strong distortion in the consumption/leisure decision imposed by the increase in the labour income tax.

**Table 6. The impact of a government consumption shock under alternative fiscal rule instruments (*PESSOA*)**

| | **Central scenario** | | | **Consumption tax rule** | | | **Lump-sum tax rule** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** |
| **CPI inflation** | 0.2 | 0.2 | -0.3 | 0.3 | 0.6 | -0.4 | 0.2 | 0.2 | -0.3 |
| **Real GDP** | 0.8 | -0.9 | -0.5 | 0.9 | -0.8 | -0.2 | 0.9 | -0.6 | -0.1 |
| ***Multiplier*** | *1.4* | - | - | *1.9* | - | - | *1.7* | - | - |
| **Fiscal balance** | -0.6 | 0.0 | 0.1 | -0.5 | -0.2 | 0.0 | -0.6 | 0.0 | 0.1 |
| **Public debt** | -0.3 | 0.7 | 0.7 | -0.4 | 0.5 | 0.6 | -0.3 | 0.6 | 0.5 |

**Notes:** See explanatory notes in Table 4.

The impact of the alternative adjustment instruments is found to be far less important in **BdF-GIMF**: simulations featuring alternative fiscal policy rules are giving the same impact multipliers. One possible explanation for the robust estimates of fiscal multiplies is the particular specification of fiscal policy rule employed in **BdF-GIMF**: since the effect of fiscal policy on GDP is directly taken into account in **BdF-GIMF**, the government tries to minimize the distortionary effects of its policy.

**Table 7. The impact of a government consumption shock under alternative fiscal rule instruments (*BdF-GIMF*)**

| | **Central scenario** | | | **Consumption tax rule** | | | **Lump-sum tax rule** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** |
| **CPI inflation** | 0.5 | 0.5 | 0.3 | 0.8 | 0.5 | -0.1 | 0.5 | 0.5 | 0.2 |
| **Real GDP** | 1.0 | -0.3 | -0.3 | 1.1 | -0.3 | -0.3 | 1.1 | -0.2 | -0.2 |
| ***Multiplier*** | *1.3* | - | - | *1.2* | - | - | *1.2* | - | - |
| **Fiscal balance** | -0.8 | -0.2 | -0.1 | -0.9 | -0.2 | -0.1 | -0.8 | -0.2 | -0.1 |
| **Public debt** | -0.2 | 0.5 | 0.5 | -0.2 | 0.7 | 0.7 | -0.2 | 0.6 | 0.6 |

**Notes:** See explanatory notes in Table 4.

**NiGEM** also features an automatic solvency rule, which ensures long-run government solvency by stabilising the budget deficit and the debt stock thanks to an increase in the direct tax rate. We do not run simulations with **NiGEM** under alternative fiscal rules since the available modelling option is limited to switching off/on the rule and does not allow tackling the form of the rule.

### *3.3.4. The role of the monetary policy rule*

The reaction of monetary policy is another crucial issue in implementing a fiscal scenario. Indeed, DSGE models may not converge in presence of too large shocks if monetary policy rule is switched-off. In **BdF-GIMF** and **NiGEM**, monetary authorities follow a default Taylor rule, adjusting the short-term interest rates to past levels of interest rates, output gap and inflation. As regards **PESSOA**, the nominal interest rate is taken as exogenous since in the small-open economy idiosyncratic developments are not likely to affect monetary policy decisions in the EA as a whole. Thus, the model does not contain a monetary policy rule and the stability of the nominal variables is ensured by real exchange rate developments, which have powerful impacts on trade and imposes a mechanism similar to a price level targeting.

In Table 8 we report simulation results of the same experiment as in the central scenario, except that during the first year of the scenario the monetary policy is exogenous, *i.e.* the Taylor rule is temporarily suspended and the nominal interest rate is held at its steady-state value. In this scenario we assume that the exogenous setting of the interest rate is fully anticipated, i.e. economic agents are well informed about temporary monetary policy accommodation and believe it.

Starting with the **BdF-GIMF** results, compared to Table 4, the fiscal multiplier is markedly higher when the monetary policy is accommodating during the period of the fiscal stimulus. On the contrary, in the subsequent years, fiscal multipliers are even more negative with monetary accommodation, but the net cumulated effect of monetary accommodation is clearly positive. Country-specific simulation results reveal that the gain from accommodative monetary policies depends on the inertia of the monetary policy. For instance, we find that gains are lower for the EA than for the United States.

**Table 8. The impact of a temporary government consumption shock with monetary policy accommodation**

| | BdF-GIMF | | | NiGEM | | |
|---|---|---|---|---|---|---|
| | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** |
| **CPI inflation** | 2.6 | 5.2 | 3.4 | 0.1 | 0.3 | 0.2 |
| **Real GDP** | 3.4 | 1.0 | -0.9 | 0.7 | 0.5 | 0.2 |
| ***Multiplier*** | 3.4 | - | - | 1.2 | - | - |
| **Fiscal balance** | -1.0 | 0.2 | -0.7 | -0.6 | 0.0 | 0.1 |
| **Public debt** | -2.1 | -3.0 | -3.7 | - | - | - |

**Notes:** See explanatory notes in Table 4.

As regards **NiGEM**, in the first year fiscal multipliers under alternative treatment of monetary policy differ negligibly. The multipliers mainly differ in years 2 and 3. Overall, the impact of the fiscal stimulus on GDP, private consumption, inflation and hours worked is quite similar in both scenarios, although, the impact on business and residential investment is larger under exogenous monetary policy assumption since there is no crowding out. What helps to explain the proximity of the two simulations results is the inclusion of long-term rates in the model, which are determined by forward-looking markets.

### *3.3.5. The gains from international coordination*

In the central scenario above we considered domestic fiscal expansion assuming unchanged fiscal policy abroad. The multi-country dimension of **BdF-GIMF** and **NiGEM**, however, allows us relaxing this assumption and to consider implementing a global coordinated fiscal expansion. In the coordination scenario, we assume a one-year 1% increase in government consumption simultaneously in the 5 areas constituting **BdF-GIMF** (the US, the EA, Japan, the rest of Asia and the rest of the world) and in the EA, the US and Japan in case of **NiGEM**. Similar to the central scenario, in the coordinated scenario monetary policy rules are treated endogenously. The key simulation results in case of the EA are reported in Table 9.

**Table 9. The impact of a temporary coordinated government consumption shock (results for the EA)**

| | BdF-GIMF | | | NiGEM | | |
|---|---|---|---|---|---|---|
| | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** |
| **CPI inflation** | 0.7 | 0.7 | 0.2 | 0.1 | 0.4 | 0.3 |
| **Real GDP** | 1.2 | -0.3 | -0.5 | 0.8 | 0.5 | 0.2 |
| ***Multiplier*** | 1.5 | - | - | 1.3 | - | - |
| **Fiscal balance** | -0.8 | -0.2 | -0.2 | -0.6 | 0.0 | 0.1 |
| **Public debt** | -0.4 | 0.5 | 0.5 | - | - | - |

**Notes:** See explanatory notes in Table 4.

Overall, we find that in each area the impact multiplier under coordinated fiscal expansion is slightly higher as compared to the individual implementation since the real exchange rate does not appreciate and the trade balance does not deteriorate. In **BdF-GIMF**, under endogenous monetary policy reaction, the main difference in coordinated impulses versus individual impulses simulations (for comparison see the respective simulation results in Table 4) is due to the trade contribution. When stimuli are implemented in all the areas simultaneously, there is no exchange rate appreciation. Thus, imports and exports reaction to the stimuli are of the same magnitude: there is no net leakage of the stimulus to non-participating countries. However, the gain to fiscal coordination between countries is higher when monetary policy is accommodative. Qualitatively similar results are obtained with **NiGEM** simulations. More detailed simulation results available for **NiGEM** reveal that gains from a coordinated fiscal expansion are greater for countries featuring closer trading links (see Appendix E).

### *3.3.6. Fiscal policy scenarios: some recommendations*

- The simulations conducted using the DSGE models suggest that this type of models is particularly adequate to conduct fiscal simulations. More specifically, the full specification of wealth and substitution effects altering households' intra and inter-temporal decisions can hardly be appropriately treated in traditional models. Moreover, the rigorous treatment of economic agents' expectations is critical in fiscal simulation exercises. The forward-looking behaviour of economic agents under the rational expectations assumption in DSGE models leaves these models less prone to the Lucas critique than traditional backward-looking models.
- The simulation of fiscal policy shocks crucially depends on a number of features that must be clear from the outset: the temporary vs. permanent nature of the shock; the number of periods where fiscal and/or monetary policy rules are turned off; the fiscal policy instrument on which the fiscal rule is based.

- The specification and the calibration of the fiscal rule as well as the time for which it is switched off affect the simulation results; therefore these options should be made explicit. It is recommendable to use fiscal rules based on realistic instruments like the labour income tax, not only due to the fact that it enhances the realism of the simulation, but also due to the fact that the utilisation of non-distortionary taxation might affect the results non-negligibly. The use of lump-sum tax based fiscal rules might be an interesting benchmark, though not a very realistic case.
- The role of monetary policy in the context of the implementation of the fiscal shocks is also of major importance. Simulations should always be explicit with respect to possible monetary policy reactions to fiscal shocks. It is important to have a counterfactual exercise with monetary policy rule switched on to assess the implicit monetary stimulus.
- International spillovers seem to be rather limited in multi-country DSGE models. This feature is also common in traditional macroeconometric models and is likely to be more related to the fact that DSGE models are not yet good at modelling international financial linkages (the same holds for traditional models), than to the lack of importance of international coordination and shock spillovers. Therefore, at the current juncture, gains from international coordination and shock spillovers are likely to be underestimated.

# Conclusions

The new generation of DSGE models offers a valuable contribution to the set of tools used by practitioners for conducting scenario analysis. Compared to more traditional models, they allow not only designing scenarios in a variety of ways and tackling a larger range of issues of interest, but also provide an appealing structural interpretation of scenario setups and simulation results.

There is growing evidence of a wider usage of DSGE models within the European System of Central Banks (ESCB) in preparing projections and conducting policy analysis. Still, it is fair to say, that the history of active use of DSGE models is rather short. The adoption of the DSGE approach to scenario analysis is, in many respects, an ongoing process and there is much to be learned about design, implementation and communication of DSGE-based scenario analysis. A number of national central banks of the ESCB continue to use traditional macroeconometric models along with DSGE models, thus recognising advantages and limitations of both modelling approaches. In this regard, it is important to emphasise that this study does not advocate a specific modelling approach; instead it attempts to illustrate some of the modelling issues that often arise when implementing scenarios using DSGE models in the context of projection exercises or policy analysis. These issues reflect the sensitivity of DSGE model-based analysis to scenario assumptions, which in more traditional (macroeconometric) models is apparently less critical, such as, for example, scenario event anticipation and duration, as well as the treatment of monetary and fiscal policy rules.

Forward-looking behaviour embodied in DSGE models implies that simulation results will crucially depend on whether the realisation (size and timing) of a scenario event is anticipated or completely unknown and, hence, a full surprise to economic agents. The advantage of such a distinction (anticipated vs. unanticipated events) is that it allows implementing more realistic scenarios where economic agents (markets) react to news as they arrive. The specific choice of whether to treat shocks in simulations as either anticipated or unanticipated depends on a number of considerations as, for example, the model estimation strategy, the type of simulation exercise, etc. While there are no rigidly applicable rules, the choice eventually may depend on how much of the information concerning the scenario event is publicly available and used by economic agents.

The treatment of interest and exchange rates in model simulations represents another example of critical assumptions, which bear important implications for scenario analysis. The setting of the nominal interest rate, typically described by a monetary policy rule, is a fundamental part of the model adjustment mechanism as, following a shock, households and firms adjust their plans by taking into account the expected response of the monetary authority. The endogenous monetary policy rule provides the nominal anchor to the model and often incorporates a smooth interest rate reaction to shocks in the short run. The nominal exchange rate, which is usually described by the uncovered interest parity condition, plays a similar stabilising role, notably in small open-economy models. The imposition of exogenous paths for interest and exchange rates, as often practiced in projection exercises, may significantly affect simulation results and their interpretation. For modelling consistency reasons, an endogenous treatment of interest and exchange rates in model simulation exercises is therefore advisable. Any scenarios featuring alternative treatment of interest and exchange rates should be prudently compared against such a benchmark case. Arguably, in projection-related simulations the assessment of the macroeconomic implications of alternative interest rate paths is of interest to policymakers. However, the evolution of future interest rates should ideally be a function of economic fundamentals, and not be determined in an *ad-hoc* manner. In this regard, "constant interest rate" scenarios make sense only if there is a good story of how the constant interest rate will be achieved and how this will be communicated to the market. Otherwise, interpretations of such scenarios will lack a solid basis.

Numerous fiscal scenarios discussed in this study show that the DSGE model-based simulation results crucially depend on a number of features that must be clear from the outset: the temporary vs. permanent nature of the shock; the specification of the fiscal policy rule and its treatment in model simulations; the assumption about the reaction of monetary policy. Differences in model reactions to temporary and permanent shocks can be related to the extent to which these shocks induce changes in permanent income and generate substantial wealth effects. Alternative specifications of the fiscal policy rule (the choice of the fiscal instrument) affect the size of economic distortions, which in turn influence agents' decisions regarding leisure and consumption. Alternative treatment of monetary policy (constant vs. endogenous) in fiscal simulations governs the strength of possible crowding-out effects and, thus the size of fiscal multipliers. The international spillovers of fiscal shocks are found to be rather limited in the current vintage of DSGE models. The latter finding may reflect the fact that modelling international financial linkages in DSGE models is not yet satisfactory. Therefore, gains from international coordination and shock spillovers are likely to be underestimated. Overall, the study demonstrates that DSGE models are particularly useful for conducting fiscal scenarios: the full specification of wealth and substitution effects affecting households' intra and inter-temporal decisions can hardly be treated in more traditional models.

# References


Andrle, M. (2006). *Essays on Fiscal Policy in DGE*, PhD thesis.

Andrle, M. (2008). "Tools for Analyzing DSGE Models Dynamics – Simulation & Filtering," mimeo, presented at DSGE Forecasting Workshop, Czech National Bank, November.

Andrle, M., T. Hlédik, O. Kameník and J. Vlček (2009). "Implementing the New Structural Model of the Czech National Bank," Working Paper 2, Czech National Bank.

Baxter, M. and R. King (1993). "Fiscal Policy in General Equilibrium," *American Economic Review*, vol. 83, 315–334.

Blanchard, O. J. and C. M. Kahn (1980). "The Solution of Linear Difference Models under Rational Expectations," *Econometrica*, Econometric Society, vol. 48(5), July, 1305–1311.

Blanchard, O. and R. Perotti (2002). "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output," *Quarterly Journal of Economics*, vol. 117(4), 1329–1368.

Christoffel, K., G. Coenen and A. Warne (2008). "The New Area-Wide Model of the Euro Area: A Micro-Founded Open-Economy Model for Forecasting and Policy Analysis," Working Paper 944, European Central Bank.

Christoffel, K., G. Coenen and A. Warne (2007). "Conditional versus Unconditional Forecasting with the New Area-Wide Model of the Euro Area," European Central Bank, mimeo.

Corsetti, G., A. Meier and G. Müller (2009). "Fiscal Stimulus with Spending Reversals," Working Paper 106, May, International Monetary Fund.

Galí, J., D. Lopez-Salido and J. Vallés (2007). "Understanding the Effects of Government Spending on Consumption," *Journal of the European Economic Association*, MIT Press, vol. 5(1), 227–270.

Forni, L., L. Monteforte and L. Sessa (2009). "The General Equilibrium Effects of Fiscal Policy: Estimates for the Euro Area," *Journal of Public Economics*, 93, 559–585.

Freedman, C., M. Kumhof, D. Laxton and J. Lee (2009). "The Case for Global Fiscal Stimulus," Staff Position Note, March, International Monetary Fund.

Galí, J., D. Lopez-Salido and J. Valles (2007). "Understanding the Effects of Government Spending on Consumption," *Journal of the European Economic Association*, 5, 227–270.

Hansen L. and T. J. Sargent (1991). *Rational Expectations Econometrics*, Boulder: Westview Press.

Heer, B. and A. Maußner (2005). *Dynamic General Equilibrium Modelling*, Springer.

Jakab, M. Z. and B. Világi (2008). "An Estimated DSGE Model of the Hungarian Economy," Working Paper 9, Magyar Nemzeti Bank.

King, R. G. (2000). "The New IS-LM Model: Language, Logic, and Limits," *Economic Quarterly*, Federal Reserve Bank of Richmond, vol. 83(2), 45–103.

Klein, P. (2000). "Using the Generalized Schur Form to Solve a Multivariate Linear Rational Expectations Model," *Journal of Economic Dynamics and Control*, Elsevier, vol. 24(10), September, 1405–1423.

Kumhof, M. and D. Laxton (2007). "A Party Without a Hangover?" Research Paper 43, International Monetary Fund.

Leeper, E. M. and T. Zha (2003). "Modest Policy Interventions," *Journal of Monetary Economics*, Elsevier, vol. 50(8), November, 1673–1700.

Lippi, M. and L. Reichlin (1994). "VAR Analysis, Nonfundamental Representations, Blaschke Matrices," *Journal of Econometrics*, Elsevier, vol. 63(1), July, 307–325.

Lubik, T.A. and F. Schorfheide (2004), "Testing for Indeterminacy: An Application to U.S. Monetary Policy," *American Economic Review*, vol. 94(1), 190–217.

Lucas, R.E. Jr. (1976). "Econometric Policy Evaluation: A Critique," Carnegie-Rochester Conference Series on Public Policy, 1, 19–46.

Manteu, C. and C. Martins (2009). "Assessing the Economic Impact of the Fiscal Stimulus Plans with the NiGEM Model," Economic Bulletin, Banco de Portugal.

Marimon, R. and A. Scott (1999). *Computational Methods for the Study of Economic Dynamics*, Oxford University Press.

Mountford, A. and H. Uhlig (2008). "What are the Effects of Fiscal Policy Shocks?" Working Paper 14551, National Bureau of Economic Research.

Schmitt-Grohé, S. and M. Uribe (2008). "What's News in Business Cycles," NBER Working Papers 14215, National Bureau of Economic Research.

Van Brusselen P. (2009). "Fiscal Stabilisation Plans and the Outlook for the World Economy," NIME Policy Brief 1, Belgian Federal Planning Bureau.

Waggoner, D. F., and T. Zha (1999). "Conditional Forecasts in Dynamic Multivariate Models," *Review of Economics and Statistics*, 81, 639–651.

Warne, A. (2008). *YADA Manual – Computational Details*, Manuscript, December 18.

Wohltmann, H.-W. and R. Winkler (2009). "Rational Expectations Models with Anticipated Shocks and Optimal Policy: A General Solution Method and a New Keynesian Example," Working Papers 1507, Kiel Institute for the World Economy.

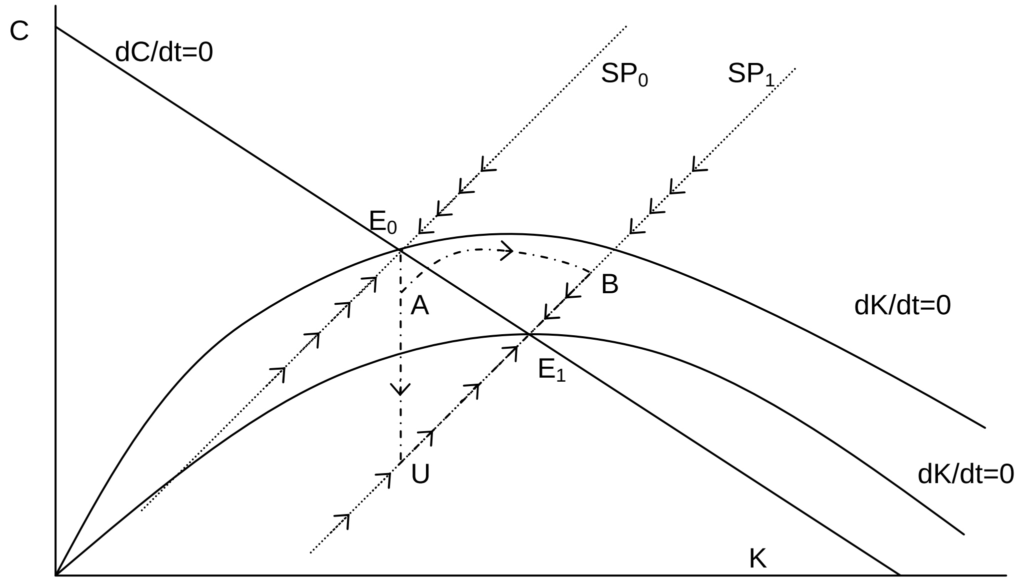
Woodford, M. (2003). *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton: Princeton University Press.

Wouter, J. and G. Kaltenbrunner (2009). "Anticipated Growth and Business Cycles in Matching Models," *Journal of Monetary Economics*, vol. 56(3), 309–327.

# A. Appendix: Sidrauski-Ramsey model

This example uses the simplest Sidrauski-Ramsey continuous-time model with endogenous labour, exogenous government spending and Ricardian equivalence present. The phase diagram in Figure A.1 displays the dynamics of the model in case of an identical and permanent increase of (pure waste) government spending. The economy moves from initial equilibrium *E0* to a new equilibrium *E1*. The difference in consumption dynamics (dash-dotted line) depends on whether government spending is increased as it is announced or whether there is a pre-implementation phase from period zero to time *T*.

**Figure A.1. Government spending shock**




**Source**: Andrle (2006).

The path *E0 – U – E1* corresponds to unanticipated increase in government spending. The economy immediately jumps on its new saddle path *SP1*. Households cut consumption and undershoot on the path to new equilibrium. On the other hand the path *E0 – A – B – E1* denotes the pre-announced government spending. The more distant the implementation period *T* is, the smaller is the initial decline in consumption and the economy does not jump immediately to a new saddle-path and follows dynamics driven both by stable and unstable eigenvalues of the model. At period *T* the saddle-path is reached (*B*) and the economy converges to a new steady state via different dynamics. Note the different welfare effects of the policy, given the consumption and labour path.

# B. Appendix: Sensitivity analysis with respect to administered prices

The following appendix has been included into the October 2007 Situation Report of the Czech National Bank (CNB) (that is a policy document regularly prepared for the Bank Board). The main motivation for including this appendix into the study was to explain why unanticipated shocks with respect to administered prices might result in better and more realistic projection compared with the option of anticipated shocks. Although the anticipated shocks are most frequently used in CNB projections, the special properties of administered prices and the way in which they are modelled in the CNB's DSGE model (g3) motivated the reliance on unanticipated shocks as well. Based on these simulations, the Bank Board agreed upon using the regulated prices projection as unanticipated with a certain degree of persistence to bring the simulations and forecasts closer to the perceived conditions prevailing in the Czech economy.

The g3 model has been developed on the basis of specification of the behaviour of consumers and firms in the economy, including the (production related and budget-) constraints they face. The specification of administered prices, therefore, requires a "structural" specification as well. The way, in which these prices are incorporated into the model, seem to be quite important. In the current version of the model the increase of administered prices, *ceteris paribus*, results in a fall of net inflation (defined as consumer price inflation without the direct effect of indirect taxes and administered prices). It is clear, that the assumption about the future path of administered prices is one of the key factors affecting the whole forecast[24].

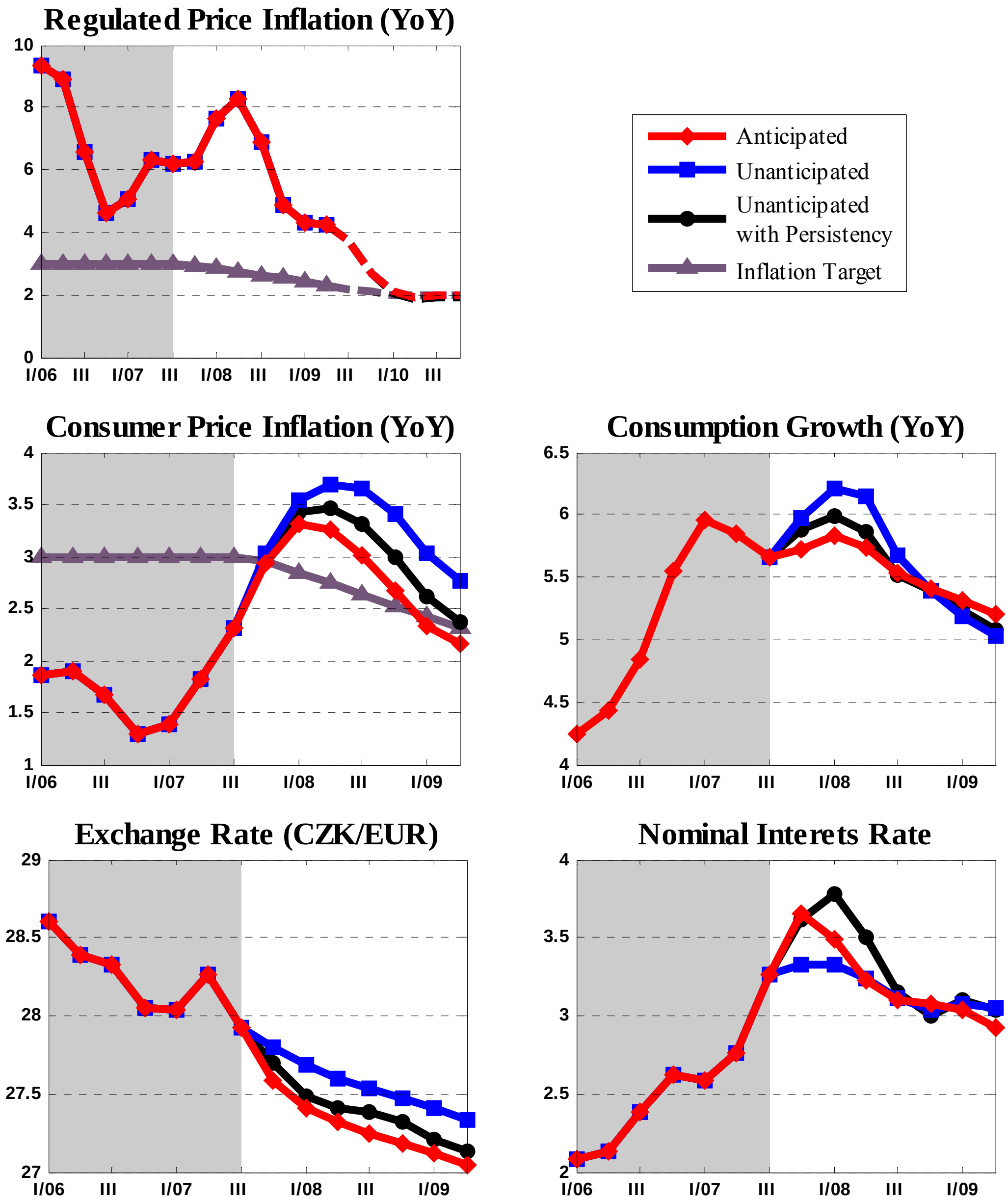
Our starting point is the baseline projection. We assume there, that exogenous variables, with the exception of government expenditure and administered prices, are fully anticipated. The observed development of administered prices surprises consumers, firms, government as well as the monetary authority. Administered prices are modelled as an autoregressive process with a persistence coefficient 0.6.

The first alternative scenario captures a simulation, where administered prices are fully anticipated. In the first period of the projection all agents in the economy - consumers, firms and the monetary authorities – learn about administered prices until the fourth quarter of 2009. They have no uncertainty regarding this information and their expectation will be perfectly fulfilled. They, however, do not know the further outlook of administered prices since the 1Q of 2010. They anticipate their gradual return to the inflation target.

[24] The incorporation of administered prices into these types of models is not entirely trivial. To our best knowledge this problem is not addressed in the currently available economic literature, colleagues from other central banks, however, are interested in how the CNB tries to address this problem in "g3". The main reason, among others, is that the model explicitly deals with more stochastic trends, which enables modellers to abandon the assumption of constant equilibrium price of administered and non-administered prices. The fact, that the model framework heavily relies on constant expenditure shares in individual sectors, is a significant limitation. The alternative approach could assume that the change in administered prices – modelled as a permanent shock – permanently affects expenditure shares. The model in this case would converge to a new steady state that would be quite difficult to calibrate and analyse.

The second alternative scenario incorporates the model with unanticipated administered prices, however with anticipated zero persistence of regulated prices by all agents in the model. Therefore, one-time jump in administered prices is assumed, that will neither be increased further nor compensated. In reality, however, these expectations will repeatedly not be fulfilled and agents will be surprised every period.

**Figure B.1. Alternative expectations about a change in administered prices**




**Note:** The simulation results are based on a DSGE model of the Czech National Bank.

Figure B.1 captures the effect of an incorporation of alternative expectation formation with respect to administered prices on y-o-y growth of CPI inflation, consumption growth, the level of CZK/EUR exchange rate and nominal interest rates.

The figures reveal that the lowest level of interest rates, the most depreciated level of the nominal exchange rate, the slowest convergence of consumption to its steady-state level and inflation to target are achieved when changes in administered prices are repeatedly unanticipated, with no persistence. Since there are no inflation pressures stemming from initial conditions, overall inflation pressures are very moderate. Therefore, monetary authorities do not feel that the rise in short-term interest rates and their effect on the economy is necessary to bring inflation back to target by increasing net inflation. Given the observed profile of administered prices, during some periods, especially in 2009, the change in regulated prices is lower than the expectation of consumers, since they extrapolate relatively high historic values of administered prices.

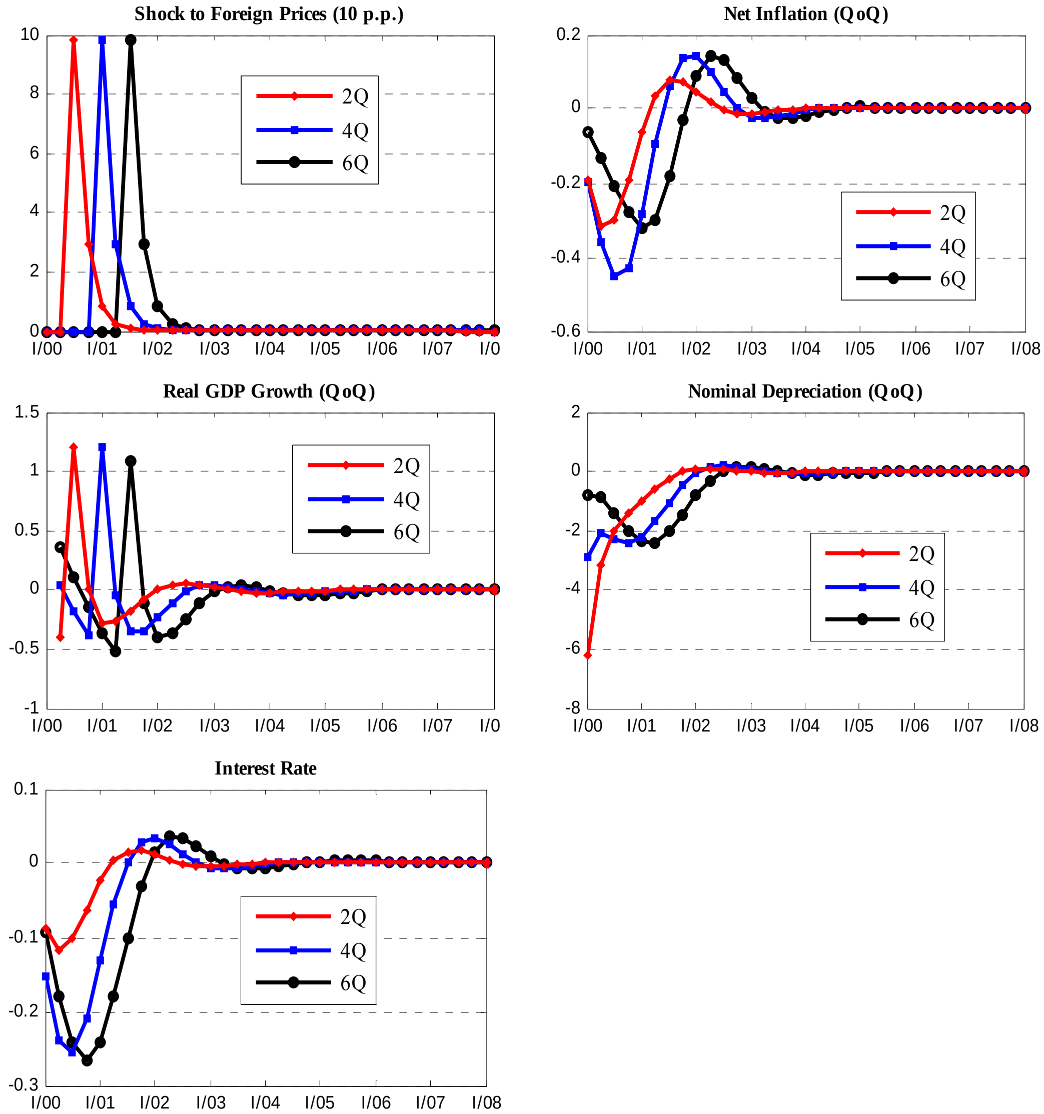
The story is different in the case, when all agents in the model perfectly anticipate the trajectory of administered prices. This clearly determines the path of net inflation that is consistent with achieving the inflation target for overall CPI inflation without the direct effect of indirect taxes. Similarly as in previous cases, the extent of the nominal exchange rate appreciation plays an important role in the adjustment process in the three considered scenarios. There is a clear trade-off between the level of short-term nominal interest rates and the appreciation of the exchange rate that is sufficient for the import of lower foreign inflation. Given the small weight of rental price in domestic intermediate prices and significant nominal rigidities, even the fall of demand for domestic intermediate products is not sufficient for the decrease of the profile of net inflation consistent with inflation targeting.

The appreciated exchange rate, through the fall of real exports, curbs domestic economic activity too. The fall in exports is not accompanied by the fall in the rate of growth of real imports. In all scenarios there is a slowdown of domestic economic activity (consumption, investment) and some increase of net foreign assets, despite the fall of labour income. The accumulation of net foreign assets is consistent with the initially higher appreciation of the nominal exchange rate than its equilibrium appreciation rate. At later stage, however, there is some correction towards lower rates of appreciation, not exceeding equilibrium.

# C. Appendix: Anticipated shock simulation with different horizon of anticipation

Based on the simulation results obtained using a DSGE model of the Czech National Bank, Figure C.1 below displays responses to an anticipated temporary foreign price shock assuming alternative horizon of anticipation (2, 4, and 6 quarters ahead).

**Figure C.1. Anticipated shock simulation under alternative horizon of anticipation**




**Note:** All responses are reported as percentage-point deviations from the model's baseline.

# D. Appendix: Multipliers corresponding to different fiscal instruments

*Multipliers in a small-open economy model*

The results obtained with the **PESSOA** suggest that the most effective fiscal instrument to stimulate demand is public consumption, which exhibit an impact multiplier of 1.4 followed by targeted transfers, which delivers an impact multiplier of 1.2 (see Table D.1). However, the transmission mechanisms are totally different. While the impact of an increase in government consumption stimulates the economy through an increase in the demand for goods used in public consumption, the increase in government transfers to liquidity-constrained households (targeted transfers) stimulates the demand for private consumption goods. The upward shift in demand leads to an increase in hours worked, which is more marked in the case of the government consumption expansion, reflecting the fact that public consumption is more intensive in labour services and has negligible import content in comparison to private consumption.

**Table D.1. The fiscal multipliers in *PESSOA*, in %**

| | **Government consumption** | | | **Transfers (untargeted)** | | | **Transfers (targeted)** | | | **Labour income tax** | | | **Consumption tax** | | | **Employers' SS contrib.** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** |
| **CPI inflation** | 0.2 | 0.2 | -0.3 | 0.1 | 0.1 | 0.0 | 0.2 | 0.1 | -0.2 | 0.0 | 0.0 | 0.1 | -1.6 | 1.7 | 0.0 | 0.0 | 0.0 | 0.1 |
| **Real GDP** | 0.8 | -0.9 | -0.5 | 0.1 | -0.5 | -0.4 | 0.7 | -0.7 | -0.4 | 0.4 | 0.0 | -0.2 | 0.3 | -0.2 | -0.2 | 0.3 | 0.0 | -0.2 |
| ***Multiplier*** | *1.4* | - | - | *0.1* | - | - | *1.2* | - | - | *0.4* | - | - | *0.5* | - | - | *0.5* | - | - |
| **Fiscal balance** | -0.6 | 0.0 | 0.1 | -0.9 | 0.2 | 0.1 | -0.6 | 0.1 | 0.1 | -0.9 | 0.3 | 0.2 | -0.6 | 0.2 | 0.1 | -0.7 | 0.3 | 0.1 |
| **Public debt** | -0.3 | 0.7 | 0.7 | 0.4 | 0.9 | 0.7 | 0.0 | 0.7 | 0.6 | 0.4 | 0.7 | 0.5 | 0.7 | 0.5 | 0.4 | 0.3 | 0.5 | 0.4 |

**Notes:** The values in the table show the deviation from the baseline level in percentage point for CPI inflation, fiscal balance (as a % of GDP) and public debt (as a % of GDP). For real GDP the percentage deviation from baseline level is presented. Since the shock is defined as an increase in government consumption of 1 % of steady-state GDP, the ex-post deterioration in fiscal balance ratio tends to fall below 1 pp., due to the endogenous response of fiscal revenues. The fiscal multiplier is obtained as the ratio of the GDP deviation from steady-state per percentage point of ex-post deterioration of the fiscal balance to GDP ratio. PESSOA reports simulations for the Portuguese economy.

Concerning untargeted government transfers to households, the multipliers are far less significant than the ones implied by both expansion of government consumption and by the targeted transfers. The difference in the multipliers reflect the lower propensity to consume of non-liquidity constrained households, which implies a limited shift in the demand for consumption goods and, therefore a smaller stimulus in the production, in particular, in what respects to non-tradable goods and hours worked in this sector.

The fiscal multipliers resulting from the cut in labour and capital income taxes, consumption tax and in employers' social security contribution rate are the lowest, being very similar to the one delivered by the increase in untargeted government transfers to households. In fact, the transmission channel of a cut in the labour income tax or in consumption tax is very similar to the one through which the increase in untargeted transfers operates, except for the fact that transfers to households are lump sum, while labour income tax and consumption tax affect the consumption/leisure decision by households. The decline in labour income tax rate implies that households earn a higher labour income for the same wage paid by firms and therefore expand their labour supply, which implies that equilibrium wage will decline on impact, contrary to what occurs in the case of the increase in government transfers. In the same vein, the consumption tax cut yields a similar impact on labour supply, since it increases the amount of consumption goods that can be purchased for the same wage. In what respects to the cut in employers' social security contributions rate, it operated mainly through an upward shift in the demand for labour creating an incentive for firms to use more labour intensive technologies and inducing an increase in wages and, eventually, a corresponding increase in labour supply. The increase in labour income stimulates the economy mainly through an increase in private consumption as in the case of the increase in labour income tax or government transfers.

As regards the pattern of the fiscal consolidation from the second year onwards, it must be highlighted that the results presented in Table D.1 assume that the expansionary fiscal measure is fully reverted and that labour income tax rate is adjusted to bring public debt to its baseline level in line with the fiscal rule. The main qualitative difference between the fiscal stimulus measures on the expenditure side (government consumption and transfers) and tax cuts is that, the reversion of the first ones implies a significant rebound in the second year, while the former does not imply such a strong rebound.

*Multipliers in a multi-country DSGE model*

In **BdF-GIMF** we implement the fiscal packages alternatively using the following set of instruments: government investment, government consumption (these two can be disentangled), labour income tax, consumption tax and government (untargeted) transfers.

The most effective fiscal instrument is government investment, followed by government consumption, consumption tax cuts, labour income tax cut, and finally government transfers being the less effective (see Table D.2). This ranking is consistent with that obtained with **PESSOA**. Note that in **BdF-GIMF** we can disentangle government investment and government consumption: our results show that the former is more efficient than the latter. For the most efficient tools, short-run multipliers are above one, which is also consistent with **PESSOA** but differs from traditional models such as **NiGEM**. As expected, government investment is the most efficient tool since it has a direct impact on aggregate demand and does not involve the forward-looking behaviours. However, there is a lag before investment can be implemented and the share of investment in government spending is limited.

**Table D.2. The fiscal multipliers in *BdF-GIMF*, stimulus in the EA, in %**

| | Government consumption | | | Government investment | | | Transfers | | | Labour income tax | | | Consumption tax | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** |
| **CPI inflation** | 0.5 | 0.5 | 0.3 | 0.5 | 0.5 | 0.2 | 0.1 | 0.3 | 0.1 | -0.1 | 0.2 | 0.1 | -1.5 | 2.1 | 0.2 |
| **Real GDP** | 1.0 | -0.3 | -0.3 | 1.1 | 0.0 | -0.1 | 0.2 | -0.1 | -0.2 | 0.3 | 0.0 | 0.0 | 0.5 | -0.1 | -0.2 |
| ***Multiplier*** | *1.3* | - | - | *1.5* | - | - | *0.2* | - | - | *0.3* | - | - | *0.5* | - | - |
| **Fiscal balance** | -0.8 | -0.2 | -0.1 | -0.7 | -0.1 | -0.1 | -1.0 | 0.0 | -0.1 | -0.9 | 0.0 | 0.0 | -0.9 | 0.0 | -0.1 |
| **Public debt** | -0.2 | 0.5 | 0.5 | -0.3 | 0.4 | 0.4 | 0.4 | 0.8 | 0.8 | 0.4 | 0.8 | 0.8 | 0.2 | 0.7 | 0.7 |

**Notes:** The values in the table show the deviation from the baseline level in percentage point for CPI inflation, fiscal balance (as a % of GDP) and public debt (as a % of GDP). For real GDP the percentage deviation from baseline level is presented. Since the shock is defined as an increase in government consumption of 1 % of steady-state GDP, the ex-post deterioration in fiscal balance ratio tends to fall below 1 pp., due to the endogenous response of fiscal revenues. The fiscal multiplier is obtained as the ratio of the GDP deviation from steady-state per percentage point of ex-post deterioration of the fiscal balance to GDP ratio. BdF-GIMF shows results for the euro area.

*Multipliers in a traditional multi-country model*

Using **NiGEM**, we implement a 1% GDP fiscal shock in the US economy along five possible tools: government consumption, government investment, government transfers, personal taxes (which do not include indirect taxes such as VAT, which are labelled as miscellaneous taxes) and corporate taxes. Solvency rule is turned-off the first year and then allowed to move. Monetary policy is reacting to the deterioration in fiscal surplus. Table D.3 shows that the ranking in the different tools effectiveness is the same as in the DSGE models, government consumption and investment being the most effective tools while transfers and corporate taxes being the less effective ones. Transmission mechanisms differ widely according to the tool: for instance, accrued government consumption and investment favour business investment while increased transfers and lower personal taxes have a larger impact on residential investment.

**Table D.3. The fiscal multipliers in *NiGEM*, stimulus in the US in %**

| | **Government consumption** | | | **Government investment** | | | **Government transfers** | | | **Personal income tax** | | | **Corporate income tax** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** | **1y** | **2y** | **3y** |
| **CPI inflation** | 0.2 | 0.6 | -0.1 | 0.2 | 0.7 | -0.2 | 0.0 | 0.1 | 0.1 | 0.0 | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 |
| **Real GDP** | 0.9 | 0.4 | 0.0 | 1.1 | 0.5 | 0.1 | 0.2 | 0.2 | 0.1 | 0.3 | 0.4 | 0.5 | 0.0 | 0.0 | 0.0 |
| ***Multiplier*** | *1.8* | | | *1.8* | | | *0.3* | | | *0.3* | | | *0.0* | | |
| **Fiscal balance** | -0.5 | -0.3 | -0.1 | -0.6 | -0.3 | -0.1 | -0.6 | -0.3 | -0.1 | -0.9 | -0.7 | -0.8 | -0.7 | -0.2 | -0.2 |

**Notes:** The values in the table show the deviation from the baseline level in percentage point for CPI inflation, fiscal balance (as a % of GDP) and public debt (as a % of GDP). For real GDP the percentage deviation from baseline level is presented. Since the shock is defined as an increase in government consumption of 1 % of steady-state GDP, the ex-post deterioration in fiscal balance ratio tends to fall below 1 pp., due to the endogenous response of fiscal revenues. The fiscal multiplier is obtained as the ratio of the GDP deviation from steady-state per percentage point of ex-post deterioration of the fiscal balance to GDP ratio. NiGEM shows results for the US.

# E. Appendix: Detailed analysis on fiscal multipliers in a multi-country traditional model

Using **NiGEM**, Barrell *et al.* (2009) quantify the effects of a one-off tax rebate, of a cut in the direct tax rate and of a cut in the indirect tax rate. In all scenarios monetary and fiscal policy rules are frozen during the first two years.

Table E.1 shows larger multipliers for the first shock, since it is a one-off payment in beginning of period. Despite a marked difference in the first year, this shock becomes quantitatively equivalent in the medium run to the second shock, which affects the direct tax evenly along the year. As a result, myopic consumers take time to change their consumption in the second shock. Moreover, multipliers for direct tax and indirect tax are not ordered the same way in all the countries: in the more financially liberalised economies, such as the US or the UK, cuts in indirect taxes would be more efficient, while the result is opposite for the EA. The multipliers obtained with **NiGEM** are generally low because of the forward-looking nature of financial markets, leading to an immediate rise in long-term interest rates, in the exchange rate and to a decrease in equity prices, generating some crowding out even if monetary policy is frozen during two years.

Table E.2 shows gains from international coordination for all types of shocks and all areas in case of coordinated fiscal packages implementation. Output gains reflect spillover effects from the stimulation of the increase in domestic GDP on the partners' exports. Therefore, the most open economies, such as Netherlands, benefit the most of the coordination.

**Table E.1. Impacts on GDP of a 1 per cent of GDP fiscal expansion (per cent change in GDP)**

| | Immediate tax rebate Year 1 | Direct tax Year 1 | Indirect tax Year 1 |
|---|---|---|---|
| **US(a)** | 0.43 | 0.29 | 0.45 |
| **UK(a)** | 0.24 | 0.17 | 0.25 |
| **Euro Area(b)** | 0.36 | 0.29 | 0.26 |
| **Belgium(a)** | 0.05 | 0.03 | 0.06 |
| **Finland(a)** | 0.26 | 0.25 | 0.24 |
| **France(a)** | 0.31 | 0.29 | 0.22 |
| **Germany(a)** | 0.32 | 0.31 | 0.28 |
| **Greece(a)** | 0.45 | 0.45 | 0.20 |
| **Ireland(a)** | 0.12 | 0.09 | 0.15 |
| **Italy(a)** | 0.19 | 0.12 | 0.24 |
| **Netherlands(a)** | 0.24 | 0.19 | 0.22 |
| **Austria(a)** | 0.14 | 0.1 | 0.12 |
| **Portugal(a)** | 0.18 | 0.11 | 0.22 |
| **Spain(a)** | 0.17 | 0.09 | 0.24 |

**Table E.2. Impacts on GDP of a 1 per cent of GDP coordinated fiscal expansion (per cent change in GDP)**

| | Immediate tax rebate Year 1 | Direct tax Year 1 | Indirect tax Year 1 |
|---|---|---|---|
| **US(a)** | 0.49 | 0.33 | 0.52 |
| **UK(a)** | 0.42 | 0.30 | 0.42 |
| **Euro Area(b)** | 0.42 | 0.32 | 0.33 |
| **Belgium(a)** | 0.22 | 0.13 | 0.10 |
| **Finland(a)** | 0.54 | 0.47 | 0.49 |
| **France(a)** | 0.46 | 0.39 | 0.34 |
| **Germany(a)** | 0.46 | 0.39 | 0.41 |
| **Greece(a)** | 0.60 | 0.55 | 0.26 |
| **Ireland(a)** | 0.22 | 0.14 | 0.17 |
| **Italy(a)** | 0.31 | 0.20 | 0.18 |
| **Netherlands(a)** | 0.71 | 0.54 | 0.55 |
| **Austria(a)** | 0.36 | 0.26 | 0.27 |
| **Portugal(a)** | 0.42 | 0.29 | 0.44 |
| **Spain(a)** | 0.28 | 0.14 | 0.28 |

**Note:** (a) Country acting alone, (b) Policy enacted in all EA countries.
**Source:** Barrell *et al.* (2009).