Fiscal Policy in Macroeconomic Models

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1. INTRODUCTION AND SUMMARY

Fiscal policy and monetary policy are, traditionally, the two most important economic instruments for stabilising movements in unemployment, output and inflation. Fiscal policy is closely linked to government budgets, relating to e.g. fixing of taxes on the revenue side and government production, consumption and investment on the expenditure side.

In Denmark, fiscal policy plays a particularly important role in stabilisation policy, given the close link between Denmark’s monetary policy and that of the euro area due to the fixed exchange rate regime. In the longer term, a sensible fiscal policy and a sustainable level of government debt are preconditions for Denmark being able to maintain a fixed exchange rate vis-à-vis the euro. In the event of weakening confidence in the Danish economy, investors will hesitate to buy Danish government bonds and demand high yields, which will have consequences for growth and employment.

A key question in relation to fiscal policy aimed at stabilising the business cycle is how the gross domestic product, GDP, changes in the short and medium term following the implementation of a given fiscal stimulus. In Denmark, such assessments have normally been performed using macroeconometric models such as the model of the Danish Economic Councils – SMEC, Statistics Denmark’s model – ADAM, or Danmarks Nationalbank’s model – MONA.

Over the last 10 years or so, a new type of macroeconomic model has attracted attention from central banks in other countries, international organisations and the research community. These models are Dynamic Stochastic General Equilibrium models, or DSGE models, which are based on forward-looking behaviour and expectations to a higher degree than macroeconometric models. This model type is also increasingly applied in analyses of the Danish economy performed by international organisations.

1 The author would like to thank Torben M. Andersen, University of Aarhus, Henrik Jensen, University of Copenhagen, and Morten O. Ravn, University College London, for valuable suggestions and comments during the preparation of the analyses in this article. Any mistakes in the article as well as the views and conclusions presented are attributable to the author alone.
This article presents a detailed analysis of the effects of fiscal policy in Denmark in a DSGE model compared with the effects in a macroeconomic model such as MONA. The analysis shows that MONA and the applied DSGE model arrive at relatively similar estimates of the effects on GDP of a temporary debt-financed fiscal expansion aimed at stabilising the business cycle. However, in some areas there are pronounced differences as regards the underlying structures and mechanisms producing the results.

The article initially looks at a debt-financed increase in government purchases of goods and services equivalent to 1 per cent of GDP, which is then reduced by around 20 per cent per quarter. Government debt is subsequently stabilised by means of taxes. The higher government purchases cause real GDP to rise by approximately 0.4 per cent in MONA and around 0.6 per cent in the DSGE model in the first quarter after the increase in government purchases of goods and services. In the subsequent quarters, the effect on GDP of the fiscal shock subsides relatively faster in the DSGE model than in MONA. The effect on GDP is zero already after 6 quarters in the DSGE model, while it takes around 15 quarters in MONA. The differences should particularly be viewed in conjunction with various assumptions regarding formation of expectations and forward-looking behaviour in the modelling of firms and households. This can be illustrated by looking at the effects on private consumption of the fiscal expansion. In the DSGE model, private consumption declines a little, as forward-looking consumers realise that their future tax payments will be higher when the increase in government debt has to be repaid some time in the future. In MONA, consumption rises slowly, peaking after approximately 1 year, since consumers in MONA make consumption decisions on the basis of current income without considering the future.

The article also throws light on the effects of a more realistic fiscal package aimed at stabilising the business cycle, consisting of a temporary easing of fiscal policy over a 2-year period. Subsequently, higher taxes will ensure that government debt returns to the initial level within 2 years from the expiry of the fiscal stimulus. The analysis using the DSGE model shows that such a fiscal package comes at a price, since unemployment will be higher and output lower after the government debt's return to its initial level. This should be viewed in light of the slow recovery of competitiveness and hence exports due to stickiness of prices and wages.

1 Lump sum taxes were applied for calculation purposes even though they are no longer part of the Danish tax system. Lump sum tax is an amount transferred from households or firms to the public sector irrespective of the circumstances, e.g. income, of households or firms. In this connection, it should be taken into account that lump sum taxes enable comparisons of the effects of the fiscal shock across the models.
Finally, the effects of the 2004 Spring Package are analysed using the DSGE model. The effects are then compared with the effects calculated in MONA. The Spring Package consisted of two parts. Firstly, it contained a number of elements to stabilise the business cycle, i.e. increased government investment, enhanced active labour market programmes and suspension of the Special Pension Savings Scheme, SP. Secondly, it contained a structural element in the form of permanently lower tax on earned income.

All else equal, suspension of a mandatory pension savings scheme should increase the propensity to consume only if consumers are credit constrained, since the suspension does not increase consumers' income viewed over their entire lifetime. A credit constraint can be an actual cap on borrowing or a substantial margin between lending and deposit rates. The forward-looking behaviour and formation of expectations thus make the DSGE model particularly well suited for modelling the suspension of SP. In the DSGE model, the SP suspension results in higher consumption only for the proportion of consumers who are credit constrained. For the remainder of the population, the effect on consumption is zero.

The Spring Package’s permanently lower tax on earned income illustrates the DSGE model's usefulness in modelling of the supply effects of a change in economic policy. In the model, permanently lower tax on earned income results in improved competitiveness, which enables higher export growth. Viewed in isolation, this contributes to permanently lower unemployment and permanently higher output.

Analyses of the Danish economy within a DSGE model framework can be a useful supplement to analyses using the Danish macroeconometric models. At the same time, such analyses provide experience with a model framework that has been used for a number of years for macroeconomic analyses, including analyses of the Danish economy, by international organisations and the economic research community. However, the two model frameworks are not substitutes for each other in all respects.

Macroeconometric models are often developed as general tools to be used in practical and detailed economic-policy planning, and they typically contain a detailed description of e.g. the tax system, government expenditures, the business structure, etc.

Conversely, the DSGE models are normally less detailed and particularly suitable for addressing issues where forward-looking behaviour and formation of expectations play a decisive role. A case in point is changes of the tax system, causing shifts in economic incentives and affecting savings and investment decisions. Another example could be labour-
market reforms with a direct impact on households' incentives regarding the work/life balance.

It should be emphasised that the analyses both in MONA and the DSGE model assume that policy-makers stick to their announced fiscal plans. This applies even though it may be tempting to deviate from the plans at a later stage. An example is if a temporary easing of fiscal policy is to be financed via higher taxes in the future.

2. ECONOMIC MODELS AND FISCAL POLICY

Economists use models as tools of their trade. An economic model is a simplified description of reality, which can support the model user's assessment of the effects of a given economic policy or of the reasons for a given economic-historical course of events. The choice of model depends on the purpose of the specific analysis.

A model can be regarded as a coherent framework that can provide a holistic picture of the various economic structures and markets. In this way, the model user avoids a fragmented analysis, and consistency is ensured in terms of compliance with identities such as the supply-demand balance.

The academic community uses models to provide a theoretical explanation of observed economic behaviour. Trade organisations, central banks, the civil service as well as international organisations all use models to analyse the consequences of structural changes in the economy, e.g. changed tax rates, and for economic projections.

Models may also serve as tools to throw light on the current economic situation. For example, it is useful to know whether an observed inflationary pressure is the result of increased demand, which could indicate that fiscal policy needs to be tightened, or whether it is the result of lower supply.

Danmarks Nationalbank’s economic models

For a number of years, Danmarks Nationalbank has used its MONA model primarily for forecasting purposes. The model is also used for calculating stress test scenarios in connection with assessments of financial stability, for simulation of political measures and for calculation of the effects of structural changes in the Danish economy. For a more detailed description of MONA, see Danmarks Nationalbank (2003).

MONA can be classified as a macroeconometric model. This also applies to the other two major economic models in Denmark, i.e. SMEC1.

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1 Simulation Model of the Economic Council.
used by the Secretariat of the Economic Councils, and ADAM\(^1\), which is maintained by Statistics Denmark and used by the Ministry of Finance, the Ministry of Economic Affairs and the Interior, the Economic Council of the Labour Movement and the Confederation of Danish Industry, among others. The short-term properties of the models are based on traditional Keynesian principles such as demand-determined output, while their long-term properties reflect supply conditions in the economy. The model framework is presented below in connection with an analysis of the effects of fiscal expansion.

Besides MONA, this article also uses a DSGE model for calculating the effects of fiscal policy. This model type has gained considerable ground over the last decade among central banks, international organisations and in the academic community. The model is characterised by a larger content of forward-looking consumers who seek to optimise their behaviour, given the economic restrictions they are facing.

DSGE models are particularly well suited for analysis of structural changes in the economy. For example, the models are better able to capture the supply effects of a change in tax policy thanks to explicit modelling of consumers’ labour supply. Other examples are the effects of announced future changes in economic policy or gradual introduction of lower taxes, which DSGE models can handle via forward-looking behaviour and formation of expectations. Another factor that should be taken into account is that the DSGE models are robust to the Lucas critique, which is reviewed in the following sections.

A more robust picture of the effects of economic policy can be achieved by applying several types of models with different analysis approaches. Thus, analyses of the Danish economy within a DSGE model framework can be a useful supplement to analyses using the Danish macroeconometric models. At the same time, such analyses provide useful experience with a model framework, which has been used for a number of years for macroeconomic analyses, including analyses of the Danish economy, by international organisations and the economic research community.

3. EFFECTS ON GDP OF INCREASED GOVERNMENT PURCHASES OF GOODS AND SERVICES

The following sections present the properties of the MONA and DSGE models through a "classic" shock to the economy in the form of increased government purchases of goods and services. The effects of this

\(^1\) Annual Danish Aggregate Model.
are compared with the results of using a vector autoregressive, VAR, model, see Ravn (2012). A stylised analysis is performed with the purpose of illustrating the differences between the model types mentioned above and throwing light on their respective strengths and weaknesses. The example thus serves both as a general presentation of the DSGE model framework and a presentation of the specific DSGE model applied in this article. Moreover, the example illustrates the theoretical issues the DSGE models are trying to address in relation to macroeconometric models such as MONA. Finally, the example estimates the effects of fiscal expansion in Denmark, but the shock cannot be perceived as an example of realistic fiscal policy aimed at stabilising the business cycle. The article later illustrates the effects of more realistic fiscal stimuli.

Specifically, this section presents the effects on real GDP of a temporary increase in government purchases of goods and services equivalent to 1 per cent of real GDP. Government purchases of goods and services are then reduced by approximately 20 per cent per quarter. This is a short-lived shock, meaning that it has no impact on the model's long-term equilibrium. The calculations in MONA assume that the higher government spending is debt-financed, and that the time of repayment is later than the calculation horizon shown. Consequently, in the calculations done with MONA, it is not necessary to specify how the debt is to be repaid. In the DSGE model, on the other hand, this must be specified, given the forward-looking behaviour. Specifically, it is assumed that the debt is stabilised by means of lump sum taxes. The calculations assume that the stimulus is not announced in advance, but that households and firms are aware, when the stimulus is implemented, of how much government purchases of goods and services will rise in excess of the planned increase, and for how long. Chart 1 shows the scenario for government purchases of goods and services.

The effect of fiscal policy is normally illustrated via multipliers. A GDP multiplier of 1 on an increase in government purchases of goods and services by 1 per cent of GDP indicates a 1-per-cent rise in GDP relative to the baseline scenario. Chart 2 shows the GDP multiplier and the effect on private consumption of the scenario for government purchases of goods and services in Chart 1.

In the first quarter, the GDP multiplier for increased government purchases of goods and services is considerably lower than 1 in both MONA and the DSGE model. This means that higher government purchases of goods and services replace other domestic demand or lead to higher imports. In the first quarters, the multipliers in both MONA and the DSGE model deviate substantially from the effect estimated in the VAR model. Both models result in a positive multiplier. Appendix 2 illustrates
that the GDP multiplier in the DSGE model can, with a high degree of probability, be expected to be between zero and approximately 0.9 for a number of alternative calibrations of the model parameters. Thus, a positive GDP multiplier lower than 1 is a very robust result.

Table 1 shows the effects of higher government purchases of goods and services broken down by items on the supply-demand balance: consumption, investment, imports and exports. The principal explanation of the fall in domestic private-sector demand in the first quarter in MONA is a drop in inventory investment. At the same time, part of the demand is met by imports. The DSGE model does not contain inventory investment, and imports are virtually unchanged.
### EFFECTS OF TEMPORARILY HIGHER GOVERNMENT PURCHASES OF GOODS AND SERVICES

**Table 1**

<table>
<thead>
<tr>
<th>Model/time after start of fiscal stimulus</th>
<th>GDP</th>
<th>Private consumption</th>
<th>Investment</th>
<th>Imports</th>
<th>Exports</th>
<th>Inventories</th>
<th>Government spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>MONA 1st qtr.</td>
<td>0.38</td>
<td>0.03</td>
<td>0.14</td>
<td>1.01</td>
<td>0.00</td>
<td>25</td>
<td>1.00</td>
</tr>
<tr>
<td>MONA 1st yr.</td>
<td>0.36</td>
<td>0.20</td>
<td>0.70</td>
<td>0.52</td>
<td>-0.09</td>
<td>6.1</td>
<td>0.40</td>
</tr>
<tr>
<td>MONA 3rd yr.</td>
<td>0.05</td>
<td>0.07</td>
<td>0.42</td>
<td>0.04</td>
<td>-0.17</td>
<td>-1.9</td>
<td>0.07</td>
</tr>
<tr>
<td>MONA 5th yr.</td>
<td>-0.04</td>
<td>0.01</td>
<td>0.15</td>
<td>0.01</td>
<td>-0.21</td>
<td>-2.9</td>
<td>0.01</td>
</tr>
<tr>
<td>DSGE 1st qtr.</td>
<td>0.78</td>
<td>0.01</td>
<td>-0.02</td>
<td>0.01</td>
<td>-0.13</td>
<td>-</td>
<td>1.00</td>
</tr>
<tr>
<td>DSGE 1st yr.</td>
<td>0.03</td>
<td>-0.05</td>
<td>-0.05</td>
<td>0.02</td>
<td>-0.24</td>
<td>-</td>
<td>0.40</td>
</tr>
<tr>
<td>DSGE 3rd yr.</td>
<td>-0.09</td>
<td>-0.05</td>
<td>-0.03</td>
<td>0.00</td>
<td>-0.07</td>
<td>-</td>
<td>0.07</td>
</tr>
<tr>
<td>DSGE 5th yr.</td>
<td>-0.05</td>
<td>-0.03</td>
<td>-0.01</td>
<td>0.00</td>
<td>-0.03</td>
<td>-</td>
<td>0.01</td>
</tr>
<tr>
<td>VAR model 1st qtr.</td>
<td>1.31</td>
<td>-0.61</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
</tr>
<tr>
<td>VAR model 1st yr.</td>
<td>0.49</td>
<td>-0.11</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.40</td>
</tr>
<tr>
<td>VAR model 3rd yr.</td>
<td>0.11</td>
<td>-0.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.07</td>
</tr>
<tr>
<td>VAR model 5th yr.</td>
<td>0.03</td>
<td>0.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.01</td>
</tr>
</tbody>
</table>

**Note:** The Table shows the effects of an increase in government purchases of goods and services equivalent to 1 per cent of real GDP in the first quarter. The fiscal stimulus is then reduced by around 20 per cent per quarter, see also Chart 1. This means that the figures in the Table can be read as multipliers as regards the effect on GDP. For example, 0.38 in the first quarter for MONA indicates an increase in real GDP by 0.38 per cent if government purchases of goods and services are increased by an amount equivalent to 1 per cent of real GDP. 0.38 also corresponds to the percentage deviation from the baseline scenario. For the remaining variables, the figures in the Table indicate only the percentage deviation from the baseline scenario. For example, private consumption in MONA, at 0.20 per cent, is higher in the scenario with an increase in government purchases of goods and services by 1 per cent of GDP relative to the baseline scenario. The calculations have been made in MONA and the DSGE model used in this article and presented in section 6. The estimated effects on GDP and private consumption, respectively, in the VAR model are from Ravn (2012). Only the estimated effect on GDP in the first quarter and after the first year is statistically significant different from 0.

**Source:** Own calculations.

Private consumption is an important item on the supply-demand balance, accounting for around 50 per cent of GDP. In the first quarter, the effect on consumption from higher government purchases of goods and services is almost zero in both MONA and the DSGE model, cf. Chart 2, right. Subsequently, private consumption in MONA rises slowly, peaking after approximately 1-1½ years, when consumption is around 0.2 per cent higher than it would have been without the fiscal expansion. The volume of investment in MONA follows the same overall trend as private consumption, but with slightly stronger effects. After the surge in imports in the first quarter, imports slowly decline, to 0 after approximately 2 years. In contrast, the consumption, investment and import effects in the DSGE model are almost 0 in the entire scenario. Appendix 2 shows that domestic private-sector consumption in the DSGE model contributes negatively to the GDP multiplier for a number of alternative calibrations of the model parameters. A negative consumption effect in connection with higher government purchases of goods and services is thus a robust model result.
Thus the GDP multipliers in the two models are produced by substantially different underlying mechanisms. The driver of the multiplier in MONA after the first year is private consumption, which is not reflected in the VAR model. The empirically estimated effect on private consumption in the VAR model is negative. It should be noted, however, that the estimated effect in the VAR model is only marginally significantly different from 0.

On the other hand, the models both reflect the decline in exports as a mechanism that contributes to returning the multipliers to 0 in the longer term. However, the fiscal effects decline more slowly in MONA, and the fiscal effect on GDP in MONA is positive up until 5 years after the implementation of the fiscal expansion. In contrast, the effect on GDP is negative in the DSGE model already after 5-6 quarters.

Explanation of effects in MONA of higher government purchases of goods and services

The following section outlines the mechanisms behind the GDP multiplier for government purchases of goods and services in MONA. A similar analysis for the DSGE model is presented in section 9 after a description of the applied model and a more general description of the DSGE model framework. For an in-depth explanation of the MONA multiplier, see Danmarks Nationalbank (2003).

In MONA, output is demand-determined in the short term, since prices and wages are seen to be given. This can be justified by the costs of adjusting prices or by prices and wages being fixed in long-term contracts and collective agreements. The increased demand caused by the fiscal expansion is therefore reflected in higher output and not in higher prices and wages. In the first quarter, the increased demand is partially covered by higher imports and depletion of inventories. The import ratio is particularly high in the first quarter, since a portion of government purchases of goods and services is spent directly on imports. In MONA, inventories are depleted, since the model assumes that it takes time for domestic output to adjust sufficiently to the higher demand for domestic products. In the subsequent quarters, output adjusts to demand, and imports decline. The higher output entails higher income for consumers, which increases private consumption and investment, in turn boosting output. MONA thus has a Keynesian multiplier, which is the principal multiplier reflected in Chart 2.

In the longer term, the levels of prices and wages respond to changes in unemployment and output, meaning that in the longer term output will be determined by supply-side factors. The increased activity leads to higher employment, which pushes up wages and prices. This makes pro-
duction relatively more expensive in Denmark compared with other countries, resulting in deteriorating competitiveness and lower exports. The decrease in exports causes output to fall back towards the starting point. These effects prompt the impact on GDP of the fiscal expansion to die out gradually.

4. MONA AND ECONOMIC THEORY

In principle, a model’s relationships should be theoretically sound and at the same time describe data exhaustively. In practice, however, it is not so easy to encompass both data and theory conformity. Against this backdrop, MONA can be regarded as a compromise between the two aspects. The following section describes how some of the compromises in MONA make the model less suited for analysing the effects of economic policy changes and more suited for economic projections.

MONA’s consumption function
A recurrent theme in this article is the treatment of private consumption in the two different model types. This simplifies the analyses and makes them more specific. In MONA private consumption, $c_t$, is, in principle, modelled as a function of income, $x_t$, and wealth, $W_t$, as follows:

$$c_t = x_t^\beta W_t^{1-\beta} e^{e_t^C}, 0 \leq \beta \leq 1 \quad (1)$$

The parameter $\beta$ determines the consumption effect of higher income or wealth and is estimated on the basis of historically observed links by means of econometric methods. $e_t^C$ is an error term in the econometric equation. In MONA, wealth comprises private-sector financial wealth plus the value of the stock of housing and passenger cars as well as pension wealth after tax. Income consists e.g. of earned income, transfers and net interest after tax.

Consumers are not forward-looking in MONA
Consumption in MONA is determined only by current and previous levels of wealth and income. MONA’s absence of a forward-looking aspect and of modelling of expectation formation implies e.g. that households do not take future fiscal policy into account. For example, they are unable to distinguish between a temporary tax cut, followed by a tax increase the following year, and permanently lower taxes. It is up to the model

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1 Specifically, MONA’s consumption function, equation (1), is estimated by means of an error correction model, cf. Danmarks Nationalbank (2003).
user to take the specific financing into account when using the model for analysis of the effects of fiscal policy. In the model, consumers have the same approach to both tax adjustments based on the average covariation between consumption and disposable income over the historical estimation period.\footnote{There are models within the macroeconometric model framework in which consumer expectations are based on projections against the background of certain empirical links. But this type of formation of expectations is still backward-looking to a certain extent, since it is estimated on the basis of historical data and thus does not take expected future changes of economic policy into account. Moreover, an optimising agent forms expectations of the future by using all endogenous variables in the model to form the expectations, not just a subset of expectations.}

**Economic policy changes the MONA relations – the Lucas critique**

The lack of forward-looking behaviour and formation of expectations in macroeconometric models implies two important problems for this model framework. A third problem in relation to MONA is that the model parameters, e.g. the marginal propensity to consume, \( \beta \), in equation (1), are not necessarily constant in the event of changes in economic policy. For example, the marginal propensity to consume can be perceived as a function of consumer preferences and parameters determining the course of economic policy. Changes in economic policy can be expected to influence the marginal propensity to consume and thus interrelations in the economy in ways that the models can only handle with difficulty. The model results can thus be misleading. This is the essence of the Lucas critique.\footnote{The Lucas critique is named after Robert E. Lucas Jr., who e.g. won the Nobel Prize for Economics in 1995 for this work.}

Lucas criticised the macroeconometric models for not being structural and thus for not taking into account that the model parameters e.g. depend on the economic policy pursued. The coefficients in the economic models are estimated on the basis of historical data and thus the interrelations in the economy that applied under the economic policy pursued in the past. A changed economic policy can cause consumer behaviour – and thus the coefficients in the model – to shift. Against this background, Lucas argued that it is difficult to have confidence in calculations of effects of economic policy based on such models, see also the example in Box 1.

In practice, it is difficult to quantify the importance of changed parameters to economic projections conditional on an alternative economic policy. Lucas argued that without knowledge of which parameters are constant and how they may possibly change if economic policy is changed, analysis of the effects of alternative economic policy using a macroeconometric model is problematic.\footnote{Lucas and Sargent (1987).} It is worth noting that this
The Lucas critique mainly relates to the use of models for projections under changed economic policy preconditions. Projections assuming unchanged economic policy in a model such as MONA do not present problems in relation to the Lucas critique. This should be viewed in conjunction with the possibility that projections on the basis of the estimated reduced equations can be sufficient if economic policy can reasonably be assumed to be unchanged – both during the projection period and during the historical period for estimation of the macroeconometric model.

EXAMPLE ILLUSTRATING THE LUCAS CRITIQUE

The following simplified model can be regarded as an explicit example of the Lucas critique. Let $y_t$ be the only endogenous variable in a model, and let $x_t$ be an exogenous variable representing economic policy in the model. For example, the endogenous variable could be private consumption, and the exogenous could be the policy rate. The variables have the following dynamics in the model:

\[
\begin{align*}
  x_t &= \rho x_{t-1} + \epsilon_t \\
  y_t &= \alpha E_t[y_{t+1}] + \beta x_t
\end{align*}
\]

$\epsilon_t$ is a stationary stochastic shock to the economy with a mean value of zero and finite variance. $|\rho| < 1$ and $\alpha < 1$ are assumed, so that the model has a solution. The solution for the endogenous variable can be written as:

\[
y_t = \sum_{j=0}^{\infty} \alpha^j E_t[x_{t+j}]
\]

Rational expectations are assumed in the model in order to solve it. This is a simplifying assumption, which basically has nothing to do with the Lucas critique. The model solution can be found by means of other assumptions on formation of expectations in the economy.

The relationship between the two variables in the example when the model is solved – the reduced form – can be found by applying the policy rule for $x_t$. The result is the following relationship between the endogenous and the exogenous variables:

\[
y_t = \frac{\beta}{1-\alpha \rho} x_t
\]

A shock to the policy variable, $x_t$, implies a change in the endogenous variable by $\beta (1-\alpha \rho)$, which depends on the policy parameter $\rho$. The Lucas critique is illustrated by effects on the endogenous variable, $y_t$, of a change in the policy variable, $x_t$, depending on the policy rule (the policy parameter $\rho$).
5. DSGE MODELLING

DSGE models are a type of model that seeks to overcome the Lucas critique by explicitly containing structural relations, i.e. model relations that are invariant to an economic policy change and to external shocks to the economy. At the same time, the DSGE models contain expectations and forward-looking behaviour. The development of the DSGE models was originally initiated in response to the Lucas critique, and since then the literature has played a large role in the development of macroeconomic models.

Dynamic Stochastic General Equilibrium models
The key aspects of the DSGE model framework can be outlined as follows:

- **Dynamic**: In a DSGE model, the economy is described as a dynamic system, reflecting the decisions of economic agents concerning a number of macroeconomic variables relating to both the future and the present. The dynamic decisions provide scope for forward-looking behaviour.

- **Stochastic**: In each period, the markets are hit by a number of shocks shifting the general equilibrium in the economy and introducing uncertainty and economic fluctuations. Together with forward-looking behaviour, the uncertainty provides a role for the formation of expectations, which are often formed rationally by forward-looking agents.¹

- **General equilibrium**: General equilibrium in the economy is the result of markets acting as forums for the coordination of decisions made by economic agents. The behaviour in the model is determined on the basis of structural equations that are constructed according to microeconomic theory, i.e. the models have a microfoundation, see Box 2.

Re Dynamic
The model enables forward-looking behaviour and expectations to play a key role by modelling decisions on savings on the consumer side and intertemporal optimisation of inputs and prices as regards firms.

Most of the DSGE literature assumes that expectations are formed rationally wholly or in part. Rational expectations imply that households and firms do not systematically commit errors, and are also known as model-consistent expectations. A substantial advantage of rational ex-

¹ The method of stochastic modelling in the DSGE models is another substantial difference between macroeconometric and DSGE models. In macroeconometric models, the residuals are seen as model errors. In DSGE models, these residuals, or stochastic shocks, may instead be given a structural interpretation, such as shocks to productivity, demand, etc. However, the literature has questioned whether some of the shocks are actually structural. The critique is presented in section 7.
The message of the Lucas critique is that if a model user wants to analyse the consequences of an economic policy change, the structures in the model must remain invariant to policy changes, i.e. the model must be structural. A microfoundation for a macroeconomic model is a method for ensuring this.

Lucas and Sargent (1987) define a structural model as a model with an unchanged structure in the event of an economic policy change; only parameters in reduced form will change. For example, this means that the willingness of households to move consumption from today into the future with a given real interest rate, a structural parameter, is unchanged in the event of an economic policy change. But the reduced relationship between consumption and interest rate, i.e. the correlation between the two variables in a model solution, may not be assumed to be constant in the event of an economic policy change, since the reduced correlation will depend on household expectations of the policy pursued, among other factors, e.g. how the central bank responds to inflation. This means that if a model describes the relationship between interest rate and consumption based on historical macroeconomic data, the model will not be able to fully capture the effects of how interest-rate adjustments are reflected in a projection based on a policy change.

Models with microfoundations focus on the macroeconomic consequences of individual decisions instead of models founded directly on observed relationships between macroeconomic aggregates. A microfoundation provides explicit specification for all economic agents: households, manufacturers, the central bank, the public sector, etc., their objectives given the amount of information and constraints they are facing. The objectives are maximisation of household welfare, utility, profits for firms and for the central bank e.g. minimisation of deviations between actual inflation and the inflation target. An example of economic constraints for households is their budgets. Economic equilibrium is found via the agents’ interaction in the markets of the model economy, typically product and goods markets.

In principle, a microfounded model is robust to the Lucas critique, as an economic policy change in a now structural, microfounded model only modifies the rules of the game through the agents’ constraints and consumer behaviour given these changed rules of the game. This is opposed to non-structural, non-microfounded models for which an economic policy change will also change the actual structure of the model and e.g. relationships between consumption, income and taxes, since they are based on observed historical relationships under the previous economic policy.
tion optimally in the formation of their expectations of future economic developments. Rational expectations can be viewed as a point of reference at which economic agents are assumed to know everything except the size of random (exogenous) shocks to the economy. In this context, macroeconometric models with backward-looking expectations can be regarded as the opposite point of reference.

One implication of rational expectations is that households in the economy are able to calculate fiscal sustainability accurately. Rational expectations thus imply that the households in the models can and will calculate accurately how much their current and future tax payments must increase in the event of fiscal expansion to ensure that fiscal policy remains sustainable in future. They also entail e.g. that consumers know and can observe that fiscal policy is generally sustainable for fiscal experiments. These are obviously strict assumptions, which help to explain *inter alia* why rational expectations should be seen as a point of reference.

Expansionary fiscal policy can result in positive effects on GDP in DSGE models even though such models are based solely on rational expectations. These effects do not arise because agents do not understand or cannot see what is happening in the economy, but they result e.g. from frictions and nominal stickiness such as price and wage stickiness. This means that firms e.g. act in their own interest when increasing production in order to accommodate rising demand from the government sector, and that households act in their own interest when increasing the supply of labour.

**Re Stochastic**

In the DSGE models, business cycles are driven by stochastic shocks. Together with an assumption about optimising households and firms, this means that business cycles are the best response, given the economic constraints, to such stochastic shocks. Economic policy aimed at stabilising the business cycle can bring the economy back towards equilibrium faster.

**Re General Equilibrium**

In order to avoid misunderstandings, it is important to clarify how to understand the "General Equilibrium" concept in DSGE models. In an equilibrium in a DSGE model, the following two conditions apply. Firstly, households and firms have performed as well as could be expected given their budget and demand, respectively. Secondly, the actions of households, firms and the public sector are consistent – for example, the volume of consumer goods purchased equals that sold. General equi-
librium does not necessarily mean that e.g. unemployment is zero and that production facilities are fully utilised; it means that the balance between supply and demand in all submarkets of the economy is the result of market mechanisms. A partial equilibrium model analyses submarkets only, while not taking into account e.g. effects on other submarkets of a given change or shock to the entire economy and potential reversing mechanisms.

Most often, DSGE models contain a number of frictions. For example, the labour market may contain frictions implying that it takes time for firms to hire new staff and for workers to find vacancies. The models may thus contain unemployment in equilibrium. At the same time, the firms in the DSGE models are most often assumed to operate under monopolistic competition, entailing that prices are set higher than the marginal costs, which pushes down output to below the potential output level of the economy.

Microfoundations have other advantages than robustness to the Lucas critique
Robustness to the Lucas critique is the greatest advantage of microfoundations, but not the only one. For example, the foundation enables the model user to identify the mechanisms working to restore economic imbalances to equilibrium. As pointed out by Woodford (2003), there are two other reasons for developing microfounded models. Firstly, in principle a microfoundation allows the model user to rank and evaluate alternative economic policies according to their effects on household welfare (utility) and not only on the basis of statistical targets such as the policy's effects on fluctuations in output and inflation. Secondly, a microfoundation means that stochastic shocks can be interpreted structurally, e.g. as shocks to productivity, demand, etc.

Box 3 shows examples of how microfoundations make DSGE models more robust to the Lucas critique. Moreover, the effects of forward-looking behaviour and formation of expectations as well as the significance of structural shocks are illustrated.

Role of frictions in DSGE models
Frictions play a key role in DSGE models, including the model used in this article. Frictions enable satisfactory modelling of empirically observed links between macroeconomic variables while maintaining assumptions regarding optimising behaviour and market-determined equilibria. Frictions are necessary in order to reduce the pace of the economy's return to equilibrium. Without the frictions, the behaviour of consumers and manufacturers in the models would be adjusted at an unrealistically fast
In a DSGE model, households make the consumption and savings decisions that maximise their welfare within the framework of their budgets, 

$$c_t + \Delta a_{t+1} = r_t a_t + x_t,$$

where $c_t$ is consumption, $a_t$ is private net wealth, $r_t$ is the real interest rate and $x_t$ is income. Income, $x_t$, may consist of e.g. earned income and profits or dividend from firms in the economy. Taxes should then be subtracted and transfers added. Under normal assumptions regarding preferences, the solution to the consumer’s problem can be written as:

$$E_t[c_{t+1}] = c_t + \frac{1}{\gamma}(E_t[r_{t+1}] - \theta) + c_t^\varepsilon$$  \hspace{1cm} (1)

The parameters $\theta$ and $\gamma$ stem from the consumer utility function and are an example of structural parameters that remain unchanged in the event of stochastic shocks and economic policy changes.

Equation (1) determines the development in consumption given today’s real interest rate and consumption. In order to determine the level of today’s consumption, the consumer’s budget condition is rewritten:

$$c_t = \frac{r}{(1+r)} W_t = r E_t \left[ \sum_{s=0}^{\infty} \frac{x_{t+s}}{(1+r)^{s+1}} \right] + r a_t$$  \hspace{1cm} (2)

Equation (2) is an example of Friedman’s permanent income hypothesis, cf. Friedman (1957).

**Forward-looking behaviour and rational expectations in DSGE models**

In DSGE models, consumers are forward-looking and base today’s consumption on expectations of future incomes and thus wealth. These expectations are most often, but not always, formed rationally. If consumers have fully rational expectations, they use all information to form expectations of future income. For example, this means that consumer expectations of future income and wealth will be based on information on how other economic agents, including the central bank and the public sector, are expected to behave in the future. A change in this behaviour causes consumer expectations of the future, and thus today’s consumption, to change. For example, expectations of higher income or lower taxes in the future entail an increase in consumption already today in order to smooth out consumption over time.

This contrasts with MONA, where consumption in a given period depends on the wealth and income in the same and earlier periods, but not on future income. For example, this means that temporary higher transfers for 2 years, funded via higher marginal taxes in the future, will initially lead to an increase in consumption in MONA. In the DSGE model, the consumption effect will be zero, disregarding labour supply effects, since rational, forward-looking consumers correctly realise that their lifetime incomes remain unchanged, meaning no change in consumption either, according to equation (2).
In the DSGE model, consumers are also able to distinguish between different sources of higher income, e.g. higher wages as a result of higher productivity growth, or increased tax-funded transfers. In both cases, the marginal propensity to consume equals the parameter $\beta$ in MONA. In the DSGE model, the first case will entail consumption growth due to the increase in consumer wealth. The second case has a consumption effect of zero.

**Structural shocks**
The last term in equation (1), $c_{t}^{\epsilon}$, is a stochastic shock to the consumer discount rate. The shock thus has a structural interpretation. This allows the model user to identify the shock if it has occurred, and interpret it as stemming from the consumption function. The source of the same shock in MONA’s consumption function is not obvious, because it is a residual. The source could thus be that the model is unable to capture the observed movements in the variables, e.g. higher growth in consumption than warranted by the development in income, etc.

**The Lucas critique and structural models**
In a solution to the DSGE model, the interaction between consumption, wealth and income will be a function of both structural and policy parameters. The structural parameters determining consumption in the specific example are $\theta$ and $\gamma$. This means that these are some of the model parameters that are constant in the event of an economic policy change, e.g. a change in fiscal or monetary policy, or a shock to the economy. In the example in this Box, the policy parameters which e.g. determine monetary or fiscal policy have not been specified – for simplification purposes – but these are the parameters that change in the event of an economic policy change.

The point is that the consumer’s maximisation problem determines the relationship between macroeconomic variables and the economic policy pursued as a function of structural and policy parameters. On the basis of the model, this function is observable, allowing the model user to identify explicitly which parameters belong to which group. The model user can thus calculate how the economic relationships change in the event of an economic policy alternative. This is not possible in macroeconometric models.

Without nominal stickiness, the models would, for example, be unable to model realistic effects of changes in the policy rate. Box 4 shows how nominal frictions can be modelled in a DSGE model. This is the method applied in this article. If prices were fully flexible, monetary policy would have a negligible effect (or none at all) on the real economy. This should be compared with historical data, showing relatively substantial and pro-
NOMINAL PRICE STICKINESS IN A DSGE MODEL

The significance of price stickiness to the effects of expansionary fiscal policy is illustrated below. The modelling of sticky prices is from Calvo (1983).

For the sake of simplicity, a closed economy without investment is considered here. A representative household with eternal life maximises the sum of the expected future utility of its consumption given its budget. The maximisation problem leads to the following conditions:

\[ w_t - p_t = \gamma c_t + \phi n_t \] (1)

\[ c_t = E_t[c_{t+1}] - \frac{1}{\gamma}(l_t - E_t[\pi_{t+1}] - \rho) \] (2)

Equation (1) denotes consumers’ supply of labour, \( n_t \), for the given consumption, \( c_t \) and real wages, \( w_t - p_t \). Equation (2) denotes the future development in consumption compared with today, as a function of the nominal interest rate, \( l_t \), and the expected inflation rate, \( E_t[\pi_{t+1}] \). The parameters \( \gamma \) and \( \phi \) are structural parameters from the consumer’s utility function and determine, respectively, the consumer’s risk aversion and how much the consumer changes its supply of labour when real wages change. \( \rho \) is the consumer’s subjective discount rate.

The economy consists of a continuum of firms, each producing a differentiated product using the same production technology, with labour from households only. Moreover, all firms face the same demand function and take the aggregate price level for granted. Firms can adjust their prices only with a constant given probability of \( 1 - \theta \) in each period, irrespective of the timing of previous price adjustments. The average price duration is given as \( (1 - \theta)^{-1} \), and the parameter \( \theta \), i.e. the Calvo parameter, is thus a measure of price stickiness in the economy.

Firms that can change their prices in period \( t \) opt for the price that maximises the expected profit in the period. The optimal price, \( p^*_t \), is set as a markup, \( \mu \), depending on the degree of monopolistic competition, over the present value of expected future real marginal costs

\[ p^*_t = \mu + (1 - \beta \theta) \sum_{k=0}^{\infty} (\beta \theta)^k E_t[mc_{t+k} + p_{t+k}] \] (3)

Firms that can change their prices in period \( t \) will thus opt for a price which appears as a markup over present and future marginal costs. Equation (3) can be rewritten as a relationship between inflation and marginal costs.

\[ \pi_t = \beta E_t[\pi_{t+1}] + \lambda mc_t \] (4)

Equation (4) is the new-Keynesian Phillips curve, i.e. a relationship between inflation and economic activity and expected future inflation. The parameter \( \lambda \) is a function e.g. of the Calvo parameter, and it is positive. When marginal costs rise, firms tend to increase their prices and thus inflation. The more flexible the prices, the higher \( \lambda \), and the more pronounced the pass-through of higher marginal costs to higher inflation. Fully flexible prices thus mean that increased demand, e.g. from higher government purchases of goods and services, is only reflected as higher inflation, not as increased output.

longed effects of monetary policy, cf. e.g. Walsh (2011). Similarly, price stickiness allows fiscal expansion to be reflected not only in higher prices, but possibly also in increased output.¹

**Natural role for structural levels**

It is a common notion that policy aimed at stabilising the business cycle, such as expansionary fiscal policy or monetary policy, cannot create persistent deviations from the long-term output level. Long-term output is determined by the development in e.g. the labour force and productivity. This also applies in the DSGE model used in this article.

A deviation between the long-term output level, also known as the trend level or the natural output level, and actual output is most often called the output gap.² It plays a natural role as a point of reference for economic policy, because it reflects levels of output, unemployment, etc. that are compatible with demand in the economy. Demand that exceeds the economy's capacity limit will be reflected in rising prices and wages. In a situation with spare capacity, expansionary fiscal policy may possibly contribute to a faster return to the natural growth level than would otherwise have been the case in the economy. It is not possible to observe trend growth in GDP and thus the output gap. Instead, it is most often estimated by means of econometric techniques. One advantage of DSGE models is that they explicitly model the natural levels of output, unemployment and inflation as functions of macroeconomic variables, while also modelling the interaction between the output gap and the rest of the economy, see Box 5. In DSGE models, output gaps are most often defined as deviations between actual output and the output that would be the result of fully flexible prices. These output gaps generally vary over time e.g. due to stochastic shocks or due to the effects of economic reforms. An estimated DSGE model thus allows monitoring of an economy's structural equilibrium, which is not directly observable. In a calibrated model it is possible e.g. to analyse the interaction between the output gap and the rest of the economy in a model-consistent way.

¹ The isolated effect of price stickiness in conjunction with fiscal expansion depends on how the economy's central bank is assumed to act. In most DSGE models by far, expansionary fiscal policy leads to a higher inflationary pressure. If the central bank is assumed to have a relatively high degree of inflation aversion, it will address higher inflation by a strong increase in the policy rate. Viewed in isolation, this will offset the expansionary effects of fiscal policy. In the DSGE model applied in this article, the central bank (Danmarks Nationalbank) – in light of the Danish fixed exchange rate policy – is expected to respond to interest rates abroad (the euro area) only. The central bank in the euro area (the ECB) is assumed to fix its interest rate against the backdrop of inflation and output in the euro area.

² See Andersen and Rasmussen (2011) for a more detailed description of output gap and trend growth.
The DSGE model used in this article is a modified version of a DSGE model developed jointly by Banco de España and Deutsche Bundesbank, cf. Stähler and Thomas (2011).

The model contains a number of markets. The product market coordinates households' consumption and investment decisions and firms' output via prices and interest rates. The labour market coordinates...
firms' demand for and households' supply of labour via real wages. The financial markets coordinate households' savings decisions and firms' demand for capital via real interest rates.

The model contains two economies, Denmark and the euro area, and Denmark is modelled as a small, open economy. The euro area is modelled in the same way as the Danish economy, but is assumed to be a large economy. This means that Denmark cannot influence macro-economic variables in the euro area, while the euro area can influence demand in Denmark. Trading across the countries is coordinated via real exchange rates.

All markets have frictions in the form of price stickiness and costs of changing behaviour, e.g. by substantially changing consumption or investment relative to levels in earlier periods. Economic policy comprises fiscal policy via modelling of the public sector and monetary policy, where the latter is given from abroad as far as Denmark is concerned.

**Households**
The model contains two types of households. One type is assumed to be credit constrained, meaning that they do not have access to borrow in the financial markets, and they do not save. Consequently, the credit constrained households' consumption is based on their current disposable income. The other type has access to borrow and save in the financial markets. These households have access to the Danish and international credit markets and can borrow or save at the short-term nominal interest rate. Moreover, they do so to maximise the sum of the expected discounted utility of current and future consumption. Due to frictions, households will not change their consumption patterns too quickly, i.e. habit formation in household consumption is assumed.

**Trading between Denmark and the euro area**
Trading between Denmark and the euro area is modelled in terms of households composing their consumption by choosing between externally or domestically produced goods. All goods can be exported and imported and are regarded as substitutable. But consumers prefer domestically produced goods to externally produced goods, i.e. a home bias exists. Box 6 contains a more detailed description of the modelling of foreign trade.

The nominal exchange rate is assumed to be one and constant, but the real exchange rate is determined endogenously. The law of a price is assumed to hold true across the two economies, meaning that, all else equal, the price of a product is the same in the euro area and Denmark.
Foreign trade and competitiveness are important determinants of the rate of adjustment to shocks in the model. This Box describes the modelling of foreign trade in the DSGE model, an important driver of the adjustment to long-term equilibrium in the economy.

In the DSGE model, the consumption of Danish households, $c_t$, consists of goods manufactured in Denmark, $c_{DK,t}$, and goods manufactured in the euro area, $c_{EU,t}$. Consumer behaviour in the euro area is assumed to be equivalent to consumer behaviour in Denmark. The two product groups are weighted by the relative country sizes, $\omega$, and a parameter determining the home bias in consumption, $\psi$, as follows:

$$c_t = \omega c_{DK,t} + (1-\omega) c_{EU,t}$$

Home bias is a method for modelling that consumers, all else equal, seek to cover part of their consumption by buying domestically manufactured goods. Country size has been calibrated on the basis of population size. In the model, the degree of home bias has been calibrated with the share of domestically manufactured goods relative to total private consumption equalling the share observed in data.

In the model, consumers are assumed to minimise their costs. This implies that, in the composition of their total consumption, consumers choose the shares of Danish and foreign goods so that the costs are minimised given prices and a level for overall consumption. The solution is given as:

$$\frac{c_{DK,t}}{c_{EU,t}} = \left(\frac{\omega + \psi}{1 - \omega - \psi}\right) \frac{P_{EU,t}}{P_{DK,t}}$$

where $P_{DK,t}, P_{EU,t}$ denote producer prices in Denmark and the euro area, respectively. The relationship between the two prices denotes the real exchange rate and thus the relative costs of manufacturing in the two economies, since the nominal exchange rate is set at 1. On the basis of the equations, the consumer price index, $P_t$, in the model can be written as:

$$P_t = (P_{DK,t})^{\omega + \psi} (P_{EU,t})^{1 - \omega - \psi}$$

On the basis of the consumer price index, the relative consumption share of total real private consumption can be written as:

$$\frac{c_{DK,t}}{c_t} = \frac{P_t}{P_{DK,t}}$$
Consequently, the prices of goods manufactured in Denmark are the same in Denmark and abroad. Together with the assumption that all goods are traded across the economies, this implies that the terms of trade equal the real exchange rate. The terms of trade are defined on the basis of producer prices, meaning that changes in the real exchange rate reflect changed relative costs of manufacturing the product in question relative to abroad. Changes in the terms of trade thus reflect changes in competitiveness.

The labour market in the model

The labour market is modelled as a "search-and-match" labour market.1 In the model, unemployment in equilibrium occurs only because of frictions. A worker can be employed in the private or public sector or be unemployed. The number of unemployed is given as $U_t$. In each period, a constant share, $s^i$, of employees, $N^i_t$, is dismissed in sector $i$, where the upper sign $i$ refers to the public or private sector, respectively.2 The flow in the labour market is then modelled on the basis of the following equation:

$$N^i_t = (1 - s^i)N^i_{t-1} + M^i_t$$

The variable $M^i_t$ denotes job creation in each period and is determined on the basis of the following function

$$M^i_t = \kappa \left( U_t \right)^{\xi} \left( v^i_t \right)^{1 - \xi}, \quad 0 \leq \xi \leq 1$$

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1 The Nobel Prize in Economics in 2010 was awarded jointly to Dale Mortensen, Peter Diamond and Christopher Pissarides for their work with this modelling of the labour market.

2 There is empirical evidence for assuming a constant rate of dismissal. As shown in Hall (2005), unemployment rises not so much because of a higher rate of dismissal, but more because the dismissed are unable to find new employment. However, the analysis in this article does not consider the financial crisis and does not process Danish data.
The variable \( v^t \) denotes the number of vacancies. The parameter \( \kappa \) denotes the efficiency of job creation, i.e. how smoothly unemployed workers and vacancies are matched. The parameter \( \varepsilon^t \) denotes the percentage change in job creation following a 1-per-cent increase in unemployment. Both parameters reflect frictions in the labour market. In the event of a surge in efficiency or higher elasticity, the frictions in the labour market are reduced, and vacancies are filled with a higher degree of smoothness.

Firms determine the number of new vacancies they want to offer by considering the costs of advertising a new vacancy against the expected value for the firm of hiring a new employee. The worker fills a new vacancy by considering the advantages of taking the job in the form of wage income against the costs of continuing the search for a new job with possibly higher wages and receiving unemployment benefits in the meantime. Any variation in the number of hours worked in the economy is the result of changes in employment, and all employees thus work a constant number of hours.

Wages are determined after negotiation between employers and employees, but not all wages are negotiable in each period. Wages are thus sticky. Moreover, the labour market treats new employees differently from employees in existing jobs. The intention is to model that wages in newly advertised vacancies adapt to cyclical movements faster than wages for employees in existing jobs.

**Firms**

Profit-maximising firms manufacture the goods in the economy under monopolistic competition, since it is assumed that all firms manufacture special products by means of rented capital equipment and labour from households. Given the monopolistic competition, firms are able to set prices higher than the marginal costs of manufacturing the product in question. The deviation between price and marginal cost depends on households' willingness to exchange various types of goods. The higher their willingness to substitute one type of goods for another, the smaller the deviation. Inflation is affected when the firm finds it appropriate to change the deviation, but the impact on inflation is gradual, since prices are assumed to be sticky.

Price stickiness arises when firms are not able to adjust prices at all times, cf. Calvo (1983). The modelling of this stickiness was described in Box 4. This is a simplified modelling of the empirically observed instances of price stickiness, see e.g. Hansen and Hansen (2007). Firms can thus adjust their prices only with a fixed probability no matter when they last adjusted them.

Firms take price stickiness into account by choosing the price that maximises the discounted value of future profits. This means that ex-
Expectations of future marginal costs play a decisive role in price formation and that inflation will depend on all future real marginal costs. If firms perceive that real marginal costs will increase in the future, the firms that are able to do so will adjust prices already today.

Price stickiness means that positive shocks to demand, e.g. fiscal expansion, are not immediately reflected in higher prices. Profits are positive due to the monopolistic competition, which is why firms want to increase output at the given prices if warranted by demand. Instead, the shock is absorbed in the deviation between prices and marginal costs. The increased demand, at given prices, is thus reflected in higher output and demand for labour and not only in rising prices.

Economic policy
The basis for modelling monetary policy is that the central bank in the euro area, the European Central Bank, ECB, fixes the short-term interest rate on the basis of an active Taylor rule. The ECB will thus raise the interest rate by more than the increase in inflation, and the ECB will lower the interest rate if the output gap narrows. Due to price stickiness, the central bank in the euro area can influence real interest rates, and thus investment and consumption, via the short-term nominal interest rate. Given Denmark's fixed exchange rate policy, the short-term nominal interest rate for Denmark is assumed to be equal to the short-term interest rate in the euro area.

In the model, fiscal policy is pursued via fiscal rules responding to government debt by automatically raising revenue or reducing expenditure in the event of an increase in government debt. The public sector collects taxes on earned income, capital returns, returns on bond holdings, VAT, lump sum taxes and labour-market contributions. The public sector spends revenue on government purchases of goods and services, investment, transfers to households or public-sector employment. The model thus includes public-sector output.

The modelling of the euro area mirrors that of Denmark. The difference is that the euro area is a large, open economy, which may impact on the Danish economy, while the opposite is not the case.

Model adjustments and calibration
As mentioned earlier, the DSGE model used in this article is a modified version of the FiMod, see Stähler and Thomas (2011). The model is calibrated for Danish data. The calibration is described in Appendix 1.

The original model was calibrated for Spanish data, but Denmark is a smaller and more open economy than Spain. At the same time, monetary policy in the model is endogenous to a certain extent for Spain,
while it is exogenous for Denmark. In addition, automatic regulation of public-sector wages has been introduced, whereby public-sector wages automatically follow private-sector wages with a lag. Automatic wage regulation in the public sector (rate regulation) is a characteristic feature of the Danish labour market.

The model properties are described in section 9 in connection with an analysis of the effects leading to the GDP multiplier for increased government purchases of goods and services in Chart 2.

7. CRITIQUE OF DSGE MODELS

Since an economic model is a simplified description of reality, a model will always have certain weaknesses. The relevant issue for the DSGE literature is whether DSGE models are a valuable supplement to other model types, and thus whether the models have provided satisfactory responses to the Lucas critique, which is one of the main reasons why this model framework was developed.

The answer to that question is provided by the models' microfoundation, which basically makes the models robust to the Lucas critique. It should therefore be critically considered whether the formulation of the optimisation problems faced by the economic agents in the models are microeconomically justified. A case in point is whether there are econometric estimates of the necessary parameter values. Another example is the question of whether DSGE models have merely replaced the partial ad hoc assumptions from the macroeconometric model framework with ad hoc constraints for the behaviour of economic agents, so that the only possible optimum way is for the agents to behave in the way originally envisaged by the model builder.

This issue can be illustrated by an example. Price stickiness is an important friction in the DSGE model framework. Price stickiness is often modelled using the Calvo method as described above. A key parameter in this context is the Calvo parameter, determining the degree of price stickiness. In the model, the firm receives a "signal" indicating whether or not the firm can adjust the price. In the models, this assumption is perceived as part of the production technology, so that it is constant. In relation to the macroeconometric model framework, an ad hoc assumption regarding price stickiness in DSGE models has been replaced by an ad hoc constraint on firms' price setting behaviour. It can be argued that the modelling of price stickiness is not descriptively realistic, but the modelling does provide a fair approximation to data. Furthermore, the Calvo parameter is relatively easy to calibrate and estimate on the basis of microdata.
An important assumption in the model framework is the assumption of rational expectations. The assumption implies that all or some of the economic agents are assumed to know and understand all links in the economy (the model). This is a strict assumption, which may be broadly criticised with empirical justification. The critique has been accepted within the model framework, and current research is investigating how to soften the strict assumptions. One example is the introduction of learning into the model, i.e. agents are assumed to increase their knowledge of the model over time, see e.g. Evans and Honkapohja (2001). Another example is rational inattention, i.e. it is assumed that economic agents do not rationally use all their knowledge about the model when making their choices. The reason is that there are costs associated with collecting information, see e.g. Sims (2010). However, researchers have not yet agreed on which ways are the most appropriate. Complexity is also a problem

Chari et al. (2007) and (2010) have criticised some of the structural shocks particularly in the estimated DSGE models for not being identifiable. For example, if a solution can be found for a certain DSGE model which cannot be distinguished from a solution for another DSGE model with different structures, the model is not identifiable. This situation may arise if the structure behind the shocks in the model cannot be clearly referred to a certain relation in the model, e.g. the relationship between the supply of labour and real wages, but can be explained on the basis of the same observed relations, which are the result of other reasons. Using a specific estimated DSGE model, the authors of the article show that shocks can occur via several different channels in the model which cannot be distinguished from each other given the available economic data. At the same time, they show that some shocks are very strong or very volatile compared with what could have been expected based on economic theory. Thus, there are indications that some shocks in some DSGE models are not unequivocal.

The DSGE literature most often uses linearisation in order to solve the model. Linearisation is an approximation of the actual model dynamics, requiring choice of a point around which the approximation is made. This choice can influence the model's quantitative properties.

Finally, a large share of the models in the DSGE literature are calibrated models, i.e. their parameters have been determined on the basis of information from microeconometric studies or set as equal to empirically observed relations (ratios or the like). However, information on a parameter may not always be derived directly from data. A case in point is parameters in the consumer utility function. The model user thus has a certain degree of freedom in the determination of these parameters.
The robustness of the results to alternative calibrations is analysed in Appendix 2.

8. RELATIVE STRENGTHS AND WEAKNESSES OF THE DSGE MODEL FRAMEWORK AND THE MACROECONOMETRIC MODELS

The substantial differences and different approaches to modelling behaviour in the two model types imply that DSGE models and macroeconometric models have relative strengths and weaknesses. This has consequences for the use of the two models.

**DSGE models contain fewer economic variables**

DSGE models are still being actively developed, and the DSGE model framework is relatively new compared with macroeconometric models. For example, this means that many items on the government budget have not yet been included meaningfully in detail in DSGE models. It also means that it makes no sense to calculate fiscal sustainability in DSGE models at this stage – the models assume fiscal sustainability. Macroeconometric models, on the other hand, contain more items from the national accounts and the government budget. As a result, macroeconometric models are more suitable for practical, detailed economic policy planning.

Another example is that only in the wake of the financial crisis did researchers begin in earnest to incorporate frictions in financial markets into the models. Although some examples of models with financial frictions could be found before the crisis, frictions played a minor role. Previous models generally included the assumptions that all consumers and firms can borrow funds at the same interest rate, and that the financial markets are always open, operating under complete competition, which is also the case in the DSGE model used in this article. The model assumption regarding the financial market implies e.g. complete information, perfect loan markets and that all debt is repaid. At the same time, it can be mentioned e.g. that neither a housing market nor a mortgage-credit market has been incorporated into the DSGE model used in this article.

**Specific and general tools**

One of the reasons why DSGE models are generally smaller than macroeconometric models is that DSGE models have traditionally been used to address a specific problem, and the model properties should be viewed in that light. Macroeconometric models, on the other hand, are to a higher degree constructed as more general tools, which should also
be viewed against the background of these models’ long development history.

For example, DSGE models are particularly well suited for describing the effects of monetary and foreign exchange policies, where forward-looking behaviour and formation of expectations play a key role. Macroeconometric models without forward-looking behaviour are less suited for such analyses.

Another important example is the possibility of using DSGE models to model effects of tax and labour-market reforms and other reforms that have a direct impact on the incentives of firms and households. This should be viewed in conjunction with the general robustness of the models to the Lucas critique, and their particular suitability for modelling the supply effects of certain types of economic policy measures.

9. THE EFFECTS OF FISCAL POLICY WITHIN THE DSGE MODEL FRAMEWORK AND COMPARISON WITH MONA

The purpose of the following sections is to illustrate the impacts of fiscal policy within the framework of a DSGE model for Denmark and to compare the impacts with corresponding effects in MONA. This provides a more detailed explanation of the effects and mechanisms that lead to the GDP multiplier for higher government purchases of goods and services in Chart 1, while also illustrating the model properties. The review of the effects is structured to mirror the main items on the supply-demand balance, i.e. private consumption, investment and foreign trade. The response of prices and interest rates is then reviewed, followed by the production side. Finally, the role of tax and monetary policies as regards the size of the GDP multiplier is analysed.

Increased government spending reduces household wealth and consumption

In the DSGE model, higher government spending is assumed to imply a corresponding future change in the present value of government revenue. This is the case, since fiscal policy in the DSGE model is assumed to be sustainable, entailing that the increase in government debt has to be repaid some time in the future. The assumption of rational expectations means that forward-looking consumers will and can realise this, meaning that their wealth has been reduced, see also Box 3. As a result, private consumption is reduced. In the literature, this effect is called the wealth effect on private consumption. Private consumption responds slowly, both because of the optimising households’ wish to smooth out their consumption over time, and of habit formation in household consumption.
As regards households, the negative wealth effect on private consumption is the most important derived effect of increased government purchases of goods and services, and it arises because of the forward-looking behaviour and formation of expectations. Moreover, it is one of the most important differences between the approaches to modelling higher government purchases of goods and services in macroeconometric models and DSGE models, respectively. As described in section 4, in MONA households tend to increase their consumption in step with rising income. Consequently, the two model types result in markedly different effects of higher government purchases of goods and services on private consumption. The empirical effect of higher government purchases of goods and services on private consumption estimated via a VAR model on Danish data is around zero, cf. section 3.

In the DSGE model, the wealth effect is mitigated by the assumption that a certain percentage of the consumers are credit constrained. Their consumption is therefore determined by income, which rises in step with the increases in wages and employment in the wake of higher public-sector demand, cf. Chart 3, left. The behaviour of credit constrained consumers thus corresponds to consumer behaviour in MONA.

The impact on investment depends on the duration of fiscal policy
In the DSGE model, higher government purchases of goods and services entail an increase in the input of labour in production. This means that capital becomes relatively more productive and labour relatively less productive.

This gives firms an incentive to invest more in capital per employee until the optimum relationship between capital and labour in production has been achieved. The volume of investment depends on the size of the increase in government spending and its duration and on the rate of growth in employment. However, investment reacts slowly, since the model assumes that investment costs rise in step with the volume of investment, see Chart 3, right.

Deterioration of competitiveness and thus foreign trade
In the DSGE model, firms' marginal costs increase in step with growth in output. Firms that are able to adjust their prices tend to set a higher price in order to achieve the desired margin between marginal cost and price. The increased Danish demand does not affect output abroad, since the Danish economy is too small to influence demand in the euro

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1 The response of the labour market to higher government purchases of goods and services is presented below.
area. Consequently, foreign firms do not adjust their prices, entailing that the increase in demand leads to deterioration of competitiveness for Danish firms, see Chart 4, left.

A similar deterioration of competitiveness is seen in MONA, although the effect is much smaller. The background is that price adjustments are mechanical in MONA in accordance with the estimated relations. Firms in the DSGE model, on the other hand, adjust their prices on the basis of an optimisation problem including not only the current demand and price pressure, but also future expectations; specifically all expected future marginal costs. That is why firms tend to do most of the adjustment already in the first quarter. Subsequently, demand for the firms’ goods falls due to the deterioration of competitiveness, prompting firms to lower their prices.

As a result of deteriorated competitiveness, exports of Danish goods decline, while imports rise, see Chart 4, right. The positive shock to de-
mand from higher government purchases of goods and services is thus partly offset by lower demand for Danish goods from Danish and foreign consumers. The DSGE model and MONA have these properties in common. However, imports tend to rise more strongly and exports to fall less sharply, initially, in MONA than in the DSGE model. The relatively smaller increase in imports in the DSGE model can be explained by the model assumption of full home bias in government purchases of goods and services. This means that the public sector buys only goods manufactured in Denmark.

The more pronounced the price stickiness, the stronger the fiscal effect
If prices and wages rise strongly as a result of fiscal expansion, the increased demand will not push up output. This implies that the models must contain nominal frictions to a certain degree so that the adjustment of prices to the increased demand is reduced. Price stickiness can be one of the most important frictions as regards the size of the GDP multiplier for government purchases of goods and services, if the central bank is not too aggressive in combating an inflationary pressure by raising the nominal interest rate, see Box 7.

Labour market
The effect of expansionary fiscal policy depends partly on the demand in the economy, partly on the supply of goods and input in production. If output fails to supply the goods in demand, the extra demand will be reflected in rising prices or imports and possibly in depletion of inventories, as in MONA in the first quarter after the implementation of fiscal expansion. In DSGE models in general, the labour market plays a key role as regards the effects of fiscal policy, since the supply and demand of labour must respond in order to increase output. This applies to an even higher degree in the specific DSGE model used here, since the labour market is characterised by frictions which restrain the potential supply effects from the labour market, see also section 6 and Box 7.

Stronger demand leads to higher output due to price stickiness. The higher output increases firms' demand for production factors, including labour, see Chart 5, left. In the DSGE model, the extra demand means, as regards firms, that the expected value of hiring an extra employee exceeds the costs of advertising a new vacancy. The extra vacancies are filled by bidding up real wages, which increases households' profit from accepting the job offer rather than continuing the search for another job, see Chart 5, right.

The employment effect is far weaker in the DSGE model than in MONA. This is because output mechanically determines employment in
The parameters in the DSGE model are calibrated partly on the basis of empirically observed relations, partly on the basis of microeconometric studies. This Box throws light on the GDP multiplier for government purchases of goods and services as regards dependence on the parameters for nominal frictions and frictions in the labour market. Both types of friction may potentially play a substantial role for the size of the GDP multiplier. Appendix 2 analyses the robustness of the model results to the entire calibration, not just certain elements of it, as in this Box.

**The labour market and the effects of fiscal policy**

Chart A (left) shows the difference between the GDP multiplier for government purchases of goods and services from the standard calibration in Chart 2 and the GDP multiplier that is the result of changing three parameters in turn by 1 per cent relative to the baseline scenario. The three parameter changes are: Lower training costs, a more flexible labour market and higher unemployment. All three changes increase the flexibility of the labour market. Higher unemployment in the applied model implies a higher number of job seekers, which makes it easier for firms to find new employees.

All three parameter changes increase the effect of fiscal expansion and have a positive impact on the multiplier, i.e. the more flexible the labour market, the stronger the effect of fiscal expansion.

In the model, an improvement of employment depends on the labour market’s ability to match vacancies with job seekers. This depends on the parameter $\zeta$, which denotes the number of new vacancies filled if the number of job seekers is increased by 1 percentage point. This parameter thus determines the degree of flexibility in the labour market. An increase in the parameter by 1 per cent, e.g. from 0.5 to 0.505, causes the multiplier to rise by approximately 0.0035-0.0050.

The model includes costs of opening a new vacancy. Perfect competition implies that the expected value of opening a new vacancy is pushed to zero. All else equal, lower costs of opening a new vacancy thus imply a higher number of new vacancies. This means that the extra demand may lead to higher employment and thus that output may grow correspondingly.
Finally, the number of job seekers rises. Basically, it applies that the higher the number of job seekers in the labour market, the higher the number of vacancies that can be filled, and the stronger the potential growth in employment. This implies stronger effects of increased government purchases of goods and services on GDP when unemployment is high.

**Price stickiness and the fiscal multiplier**

As shown in Box 4, nominal frictions play a key role as regards the size of the GDP multiplier. Chart A (right) shows the difference between the GDP multiplier from the standard calibration in Chart 2 and the GDP multiplier that is the result of an increase of 1 per cent in the nominal frictions relative to the standard calibration. Nominal wage rigidity means that stronger demand is not immediately reflected in the higher wages that are needed to attract the extra labour. The model provides for distinction between the degree of wage stickiness for workers in existing and new jobs. In both cases, this nominal stickiness has relatively little significance for the effect of fiscal expansion. Price stickiness, on the other hand, has a strong effect on the GDP multiplier, which rises by around 0.015.

**The multiplier if calibrations are changed**

Chart B compares the GDP multiplier for higher government purchases of goods and services calculated in MONA, the VAR model and the DSGE model with the standard calibration and two other calibrations of the DSGE model. In calibration 1, the price rigidity rises: from being unchanged for around 5 quarters on average, prices are unchanged for 10 quarters. In calibration 2, unemployment increases from around 4 per cent of the labour force to 12 per cent, while job creation elasticity is increased from $\frac{1}{2}$ to $\frac{3}{4}$.
MONA. In the DSGE model, on the other hand, firms make decisions on hiring extra employees on the basis of forward-looking behaviour, i.e. determined not only by wages and output in the current quarter, but also by expectations of future demand and wages.

The DSGE model contains two frictions that constitute an upper limit for the increase in employment within a given period, and thus for the effect of fiscal expansion on real GDP. Employment in the current period is given as employees from the preceding period who were not dismissed, plus new employees, see also section 6. The first effect relates to a given number of dismissals in each period irrespective of demand in the economy. The second effect indicates that employment can be increased only by the number of new employees, and frictions imply that job creation only happens slowly. Due to job-seeking costs, the higher demand for labour cannot be met immediately. The adjustment of labour to stronger demand thus takes time. This means that a marked rise in the number of new vacancies, or in the number of job seekers, does not cause a corresponding increase in job creation. Chart 5, right, thus shows much stronger growth in new vacancies than in the number of newly filled vacancies. The effect of fiscal policy thus depends on the degree of flexibility in the labour market, including firms' expectations regarding the value of hiring extra employees, how quickly employees

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**EFFECT ON THE LABOUR MARKET OF A TEMPORARY INCREASE IN GOVERNMENT PURCHASES OF GOODS AND SERVICES**

Chart 5

- Unemployment, DSGE
- Natural unemployment
- Unemployment, MONA
- Filled vacancies
- Advertised vacancies
- Real wages (right-hand axis)
can be hired and wage formation. All else equal, higher unemployment basically means that more vacancies can be filled. In the DSGE model, fiscal expansion may thus potentially have a stronger impact on GDP in periods of high unemployment in the economy, see also Box 7.

**Fiscal effects depend on monetary policy and the exchange-rate regime**

The central bank can influence the real interest rate via the nominal policy rate, given the price stickiness in the model, see Box 4.¹ The real interest rate affects both consumption and capital formation in the economy.² Consequently, monetary policy may potentially play a large role in the effect of fiscal policy. If the central bank addresses growing demand by raising interest rates, the effect of the higher government spending is reduced.

On the other hand, in the DSGE model used here, the policy rate is determined exogenously from abroad, i.e. by ECB, reflecting the Danish fixed exchange rate regime. This means that the nominal interest rate is fixed, and that the Danish real interest rate is determined approximatively by the development in Danish prices. When inflation increases due to stronger demand and higher marginal costs, the real interest rate falls. This stimulates consumption and points to a rather high fiscal multiplier for an economy like Denmark with a fixed exchange rate regime.

But the fixed exchange rate regime also implies that the rate of growth in wages and prices in Denmark should, in the long term, be equivalent to that abroad in order to maintain competitiveness.³ In the long term, this means that relative producer prices in Denmark, compared with those abroad, must return to the initial level from before the fiscal expansion. It also means that both inflation and the nominal interest rate, and thus the real interest rate, are given from the euro area.

Taken together, these factors mean that higher government purchases of goods and services lead to an initial drop in the real interest rate, which – all else equal – gives forward-looking consumers an incentive to increase their consumption. At the same time, these consumers realise that the future – and thus the long-term – real interest rate must necessarily rise in the future, since Danish prices must at some point in time return to the relative price level seen before the fiscal stimulus. This reduces the GDP multiplier in the longer term.

¹ The relationship between the real interest rate, inflation and the nominal interest rate is given by the Fisher equation, which denotes that the real interest rate equals the nominal interest rate less expected inflation.
² See also the modelling description of consumption in Box 3.
³ The model does not include productivity growth.
These theoretical effects are shown in Chart 6: the nominal interest rate is unchanged over the lifetime of the shock, inflation initially surges and the real interest rate falls. Subsequently, inflation falls below its equilibrium level and slowly returns to the initial level. The mirror image is an increase in the real interest rate, which puts pressure on the accumulation of capital and the development in consumption, entailing that the GDP multiplier effect slowly dies out.

**Instrument for financing higher government expenditure**

In a DSGE model, an increase in government expenditure must be offset by an equivalent rise in future government revenue (measured as present values) in order to prevent an excessive rise in government debt. This should be viewed in light of forward-looking behaviour and formation of expectations. The GDP multiplier for increased government purchases of goods and services depends on the choice of debt-stabilising instrument and on how fast the debt in the fiscal shock is to be stabilised. For example, the multiplier becomes negative in the DSGE model if the government has a target of a balanced budget at all times, see Chart 6, right.

**10. AN EXPANSIONARY FISCAL PACKAGE**

The fiscal package analysed in the previous sections is stylised. It is useful for illustration of the effects of fiscal policy, but the package is not realistic. The GDP multiplier is therefore analysed in the following section in connection with a more realistic, but still stylised, fiscal package. In this
package, the government announces a debt-financed increase in government purchases of goods and services by 1 per cent of GDP for 8 quarters, after which government debt is brought back to the initial level over the next 8 quarters. It is assumed that the debt is reduced by increasing taxes on earned income. Initially, the fiscal expansion is thus debt-financed – as in the first shock presented in this article – but in contrast to the first shock, the intention is to stabilise government debt at the level observed before the implementation of the fiscal package by a predetermined time; within the next 8 quarters. The calculations assume that the package is not announced in advance, but that households and firms receive full information on the fiscal package when it is implemented.

Although this fiscal package is more realistic than the stylised package in section 3, its implementation requires an explicit and credible political plan for government purchases of goods and services. In the absence of such a plan, it may be difficult to ensure that the total package does not entail higher or lower government purchases of goods and services over the lifetime of the fiscal package than would otherwise have been the case, whereby the planned debt stabilisation would be insufficient. At the same time, the package requires adherence to the plan and that the government actually reduces government spending after the expiry of the stimuli in the first 2 years although the debt stabilisation and the roll-back of public-sector demand could result in recession.

**Announced fiscal expansion in the DSGE model**

Chart 7, left, shows the effects on GDP of the fiscal package mentioned above. The increased demand has an expansionary effect on GDP. The mechanisms that lead to this effect correspond to the effects described in section 9. The immediate effect is very like the multiplier in section 9. However, after 2 years GDP falls below the level in the baseline scenario. This is partly because the expansion in government purchases of goods and services ceases, partly because the debt stabilisation commences, see Chart 7, right. The result is a strong tightening of fiscal policy in the period 9-20 quarters after the original shock.

The multiplier falls already from the second quarter even though government spending is maintained. This should be viewed in conjunction with price changes and foreign trade. Prices increase as output

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1 Real government purchases of goods and services are increased by 1 per cent of real GDP for two years *ex ante*. Real GDP responds already in the first quarter after the implementation of the fiscal stimulus. This means that the volume of increased government purchases of goods and services in the first quarter no longer constitutes 1 per cent of real GDP in the second quarter. During the shock, the volume of real government purchases of goods and services does not grow by real GDP, but is maintained at the volume of real government purchases of goods and services, which constitutes 1 per cent of real GDP in the first quarter.
pushes up marginal costs, see Chart 8, left. As a result of the higher prices, Danish goods become relatively more expensive than foreign goods, entailing export losses and increased imports, see Chart 8, right. This leads to deterioration of competitiveness and a resulting fall in exports and increase in imports.\(^1\) The deterioration of competitiveness lasts a relatively long time, and the recovery is not complete until after around 40 quarters. This persistent effect on competitiveness should be viewed in light of e.g. the price and wage stickiness and of Denmark being a small, open economy.

Private employment rises, and unemployment drops immediately after the implementation of the fiscal expansion, see Chart 9, left. The background to this scenario was explained in section 9. The subsequent decline in output entails a rise in unemployment from around 3¾ per cent to around 4½ per cent. The loss of competitiveness during the upswing and the resulting drop in exports contribute to the relatively persistent deviations of private-sector employment and unemployment from their respective long-term levels.

Chart 10 shows how private consumption responds to the shock. Forward-looking households' consumption falls a little, reflecting two factors: Firstly, an increase in a distorting tax, i.e. tax on earned income, with a downward impact on the demand for labour and thus output. This limits the scope for private consumption, which is realised by forward-looking and rational consumers. Secondly, households foresee higher future tax payments, i.e. a negative wealth effect, which causes them to reduce consumption.

\(^1\) The definition of the real exchange rate in the model entails that a drop in the real exchange rate reflects deterioration of competitiveness.
In the first two years with higher output, credit constrained households experience growth in real wages, i.e. higher income entailing higher consumption. The subsequent higher tax rate on earned income – implemented to finance the increased debt – and the declining real wages and rising unemployment together lead to a strong drop in the consumption of credit constrained households during the recession. The decline in total consumption during the recession is stronger than the increase during the expansion.

The above has shown the effects of a fully tax-financed fiscal expansion package, moving GDP from the future to today by means of government spending and bringing back government debt to the level prior to the implementation of the package. The review of the effects in the model has shown that both private consumption and foreign trade have a negative effect on GDP. Consumption falls because forward-looking agents realise that their future tax payments will be higher, while employment will fall at a later time. Foreign trade decreases due to the de-
terioration of competitiveness. Employment increases initially, followed by a later decrease due to lower exports, and it returns to the initial level only slowly. This should be viewed in light of price and wage stickiness. As a result, it takes around 10 years for unemployment to return to the initial long-term level.

11. THE 2004 SPRING PACKAGE IN A DSGE MODEL

In the spring of 2004, the Danish government at the time proposed an economic package, the Spring Package, intended to boost activity in the Danish economy. The effects of the Spring Package are calculated in the DSGE model below. The results are then compared with the effects calculated in MONA. The analysis throws light only on the isolated effects of the actually adopted elements of the Spring Package. Consequently, fiscal stimuli in subsequent years, which are not related to the Spring Package, are not considered in the analysis.

The Spring Package contained both measures to increase demand for output and labour in the shorter term and supply in the longer term. The Spring Package elements designed to stabilise the business cycle were frontloading of government investment by 2 years, more funds for activation of the unemployed, and suspension of contributions to the

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1 The analysis perceives the Spring Package as an exogenous shock, which was not foreseen by consumers and households.
Special Pension Savings Scheme, SP. The elements of the Spring Package that were designed to influence long-term growth included first and foremost frontloading of a tax reform, which cut income taxes. The Spring Package is described in more detail in e.g. Danish Government (2004) and Danish Economic Council (2004).

The degree of detail in the applied DSGE model is not high enough for all elements of the Spring Package to be completely incorporated into the shock. Instead, the model operates with changed parameters that can be reasonably assumed to produce the same effect as the actual elements of the Spring Package.

- The suspension of mandatory SP savings is implemented into the model by reducing the labour-market contribution
- The higher cap on second-tier tax is implemented by cutting income tax. The DSGE model thus contains only one income tax rate on earned income. This feature is also found in MONA
- The DSGE model does not contain unemployed in active labour market programmes. However, the model does contain a number of parameters for capturing potential effects of expanded active labour market programmes in view of the rather detailed modelling of the labour market. If activation is assumed to upgrade the skills of the unemployed, the effects can be captured in the model by reducing training costs for firms. If activation is assumed to entail that an unemployed person will, all else equal, rather take a job than be unemployed and continue the search for a new job, the income from continued unemployment can be reduced in the model. In this mindset, the idea behind activation is to encourage the unemployed to apply for the vacancies possibly existing in the economy. Finally, activation can be assumed to dampen the frictions in the labour market, since it gives the unemployed an incentive to accept a vacancy, while also containing a certain degree of upgrading of the qualifications of the unemployed. This is the choice in the calculations below.\(^1,2\)

When fiscal policy is changed, government debt needs to be stabilised at present value. For simplification purposes, it has been chosen to stabilise government debt through lump sum taxes, which are slowly and automatically raised after the expiry of the Spring Package after 8 quarters.

\(^1\) Specifically, the elasticity of the matching function is increased with respect to the number of unemployed, \(\zeta\). This means that when unemployment rises by 1 percentage point, the number of new matches between job seekers and new vacancies grows by \(\frac{1}{4}\) percentage point more than before the Spring Package.

\(^2\) One limitation of the DSGE model is that GDP is normalised to be 1, where fiscal policy is normally specified in kroner. As a result, the amounts stated in the Spring Package are translated into percentages of GDP at constant prices.
ECONOMIC INSTRUMENTS IN THE SPRING PACKAGE

Chart 11

Lump sum taxes are not part of the Danish tax system, but are nevertheless used in the analysis because, together with slow debt stabilisation, they make it possible for debt stabilisation not to have any great significance on the effects stated.

Chart 11 shows the implementation of the Spring Package in the DSGE model in the form of deviations of the respective economic instruments from the baseline scenario.

Chart 12, left, shows the effects on GDP of the Spring Package. The elements of the package aimed at stabilising the business cycle – not least higher government investment – increase demand. The mecha-

EFFECT OF THE SPRING PACKAGE ON GDP (LEFT) AND PRIVATE CONSUMPTION (RIGHT)

Chart 12

Note: In MONA, the calculations were stopped in 2004 after 12 quarters, given MONA’s role as a model for short-term projections of the Danish economy.
isms behind the effect of government investment on GDP are the same as the mechanisms behind the effects of government spending on GDP described in the two preceding sections. The higher degree of activation improves the labour market's ability to create jobs. As a result, the extra demand may be met by larger supply to a higher degree. This creates a stronger GDP multiplier than would otherwise have been the case.

Chart 12 also contains the Spring Package's effects on GDP. The Chart shows a good match between the effects in the two models. However, the effect of the Spring Package occurs earlier in MONA than in the DSGE model.

Total private consumption rises as a result of the fiscal expansion, see Chart 12, right. Forward-looking households realise that the higher future tax payments will erode their wealth. Credit constrained households spend part of the extra income generated by permanently lower taxes on their earned income and by higher real wages.\(^1\) In MONA, the effect on consumption is slightly stronger than in the scenario for total consumption in the DSGE model. One underlying factor is that all consumers in MONA spend their income, whereby they do not immediately take the financing of the higher government expenditure into account in their consumption decisions.

The Danish economist community expressed some degree of uncertainty about the calculation of the effects of the Spring Package back in 2004. This should be viewed in light of the uncertainty regarding the consumption effect of the individual elements of the package, especially the effect of the suspension of the SP scheme, see Box 8. As shown in Chart 12, forward-looking behaviour plays a key role as regards the consumption effect of the Spring Package. In a macroeconometric model, the reduction of tax on earned income will immediately lead to higher consumption, given the higher income. In the DSGE model, forward-looking consumers reduce their consumption as a consequence of the Spring Package due to the higher tax payments. Only if the tax cut is followed by government budget savings will forward-looking households respond to the reduction of the distorting tax by increasing their consumption.

The final element of the Spring Package was the 2-year suspension of the SP scheme. The SP scheme was a tax-deductible, individual mandatory savings scheme. The suspension entailed a minor improvement of public finances due to the lapse of tax deductibility. However, the suspension is immaterial for a forward-looking household, since its wealth

\(^1\) In the model, credit constrained consumers do not pay lump sum tax, which is why the effect of lower tax on earned income dominates.
The Ministry of Finance, the Danish Economic Councils and Danmarks Nationalbank have all previously made calculations of the effects of the Spring Package. Calculations of the effects of fiscal policy are always associated with uncertainty, because the calculations are based on an economic projection. The publications Danish Economic Councils (2004) and Danish Government (2004) indicate that the uncertainty associated with calculations of the effects of the Spring Package had an extra dimension. This is related to the effect on private consumption of the suspension of the SP scheme as well as the tax cut, on the one hand, and the degree to which Danish households would spend the additional disposable income, on the other.

For example, the Danish Economic Councils wrote: "Estimation of the effects of the tax and spring packages is associated with some uncertainty. The effects of the packages on activity are primarily the result of higher disposable real incomes, so the size of the effects basically depends on the number of øre spent on consumption out of extra real income of one krone" (Danish Economic Councils (2004), p. 66 – in the Danish text, not included in the English summary). The following was also stated: "The tax cuts are presumably perceived as a permanent increase in disposable income, whereby they probably have a relatively substantial effect on consumption."

As shown in section 9, the financing of fiscal policy may be a key driver of the GDP multiplier and not least private consumption within a DSGE model framework. This is a point acknowledged by users of macroeconometric models: "On the other hand, it can be envisaged that consumers find that there is no scope for tax cuts, which would lead to a less pronounced consumption effect." (Danish Economic Councils (2004), p. 68 – in the Danish text, not included in the English summary).

In the Ministry of Finance’s calculations of the effects, see Danish Government (2004), the activity effect also related to private consumption. The consumption effects were analysed in relation to an increase in incomes. This mindset is rooted in the macroeconometric model framework without a forward-looking aspect and without formation of expectations, not in relation to an increase in wealth, which is the case in the DSGE model framework. The calculations in Danish Government (2004) thus attach less importance to wealth effects and a forward-looking perspective, which could potentially play a key role in the consumption effect in the Spring Package, see Chart 12.

will remain unchanged. Moreover, consumers can borrow a similar amount in the financial markets if they want to consume and not save an amount equivalent to the SP savings. This is the reason why the lapse of the mandatory savings scheme has no effect on the consumption of forward-looking households, only on the consumption of credit-constrained households.

According to the calculations in the DSGE model, the short-term costs of the Spring Package are made up of loss of competitiveness due to higher price and wage pressures relative to abroad, see Chart 13.\(^1\) The
underlying mechanisms were explained in section 9. However, in the longer term competitiveness is improved by the structural element of the Spring Package, i.e. the permanent cut in tax on earned income, as explained below.

**Supply effects of the Spring Package – structural elements**

The second element of the Spring Package was a permanent tax cut on earned income. In the DSGE model applied, the lower tax entails an increase in the supply of labour. In concrete terms, the number of advertised vacancies rises due to initially lower labour costs for firms of hiring extra employees. This results in higher employment and lower unemployment.

Denmark's competitiveness is improved via lower wages. Households increase their supply of labour, which is the mechanism behind the lower wages. This results in a more moderate wage pressure in wage negotiations. The lower wages reduce firms' marginal costs, in the long term causing firms to lower their prices in order to maintain the optimum margin between costs and prices. Thanks to the improved competitiveness, the extra output can be sold abroad, while Danish consumers' demand for the now relatively cheaper Danish goods increases at the expense of foreign goods, see Chart 14. Overall, a permanent improvement of competitiveness leads to a permanent decrease in unemployment.
In the longer term, the supply effects of the permanent tax cut lead to a permanent improvement in employment via growth in market shares and lower imports. One of the key strengths of the DSGE model is its ability to make meaningful calculations of economic projections based on changed economic policy, here a changed tax rate, and modelling of the supply effects of policy changes.
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## APPENDIX A: CALIBRATION OF THE APPLIED DSGE MODEL

### Table A.1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter explanation</th>
<th>Source and explanation of value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_c$</td>
<td>2</td>
<td>Degree of risk aversion and the inverse of intertemporal substitution elasticity</td>
<td>Standard in the literature</td>
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<tr>
<td>$\omega$</td>
<td>0.017</td>
<td>Size of the Danish economy relative to the euro area</td>
<td>Statistics Denmark and the ECB</td>
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<tr>
<td>$\rho_R$</td>
<td>0.9</td>
<td>Dependence of the monetary-policy rule on interest rates in previous periods</td>
<td>-</td>
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<tr>
<td>$\varphi_x$</td>
<td>1.5</td>
<td>Impact of CPI inflation on monetary-policy rule</td>
<td>Follows a stable monetary-policy rule</td>
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<tr>
<td>$\varphi_y$</td>
<td>0.5</td>
<td>Impact of GDP on monetary-policy rule</td>
<td>Follows Taylor rule</td>
</tr>
<tr>
<td>$\bar{y}_{tot}$</td>
<td>1</td>
<td>Real GDP per capita (PPI-deflated)</td>
<td>Standardisation</td>
</tr>
<tr>
<td>$\bar{p}_A$</td>
<td>1</td>
<td>Gross PPI inflation</td>
<td>Standardisation</td>
</tr>
<tr>
<td>$\bar{p}$</td>
<td></td>
<td>Gross CPI inflation</td>
<td>Standardisation</td>
</tr>
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<td>$\bar{U}$</td>
<td>3.85</td>
<td>Unemployment rate</td>
<td>Danmarks Nationalbank, <em>Monetary Review</em>, 3rd Quarter 2011, Part 2</td>
</tr>
<tr>
<td>$N$</td>
<td>1</td>
<td>Total employment (public and private sector)</td>
<td>Standardisation</td>
</tr>
<tr>
<td>$frac{pub}$</td>
<td>0.30</td>
<td>Public-sector employment relative to total</td>
<td>MONA database (qo/q)</td>
</tr>
<tr>
<td>$N^g_t$</td>
<td>0.30</td>
<td>Public-sector employment</td>
<td>MONA database</td>
</tr>
<tr>
<td>$s_p$</td>
<td>0.06</td>
<td>Exogenous dismissal parameter for private-sector employees</td>
<td>Christoffel et al. (2009)</td>
</tr>
<tr>
<td>$s_g$</td>
<td>0.03</td>
<td>Exogenous dismissal parameter for public-sector employees</td>
<td>Afonso and Gomes (2008)</td>
</tr>
<tr>
<td>$q_p$</td>
<td>0.70</td>
<td>Job creation rate in private sector (matched per vacancy)</td>
<td>Christoffel et al. (2009)</td>
</tr>
<tr>
<td>$q_g$</td>
<td>0.80</td>
<td>Job creation rate in public sector (matched per vacancy)</td>
<td>Christoffel et al. (2009)</td>
</tr>
<tr>
<td>$\phi^p$</td>
<td>0.50</td>
<td>Job creation elasticity (coefficient in matching function), private sector</td>
<td>Pissarides (2000), standard in the literature</td>
</tr>
<tr>
<td>$\phi^g$</td>
<td>0.30</td>
<td>Job creation elasticity (coefficient in matching function), public sector</td>
<td>Afonso and Gomes (2008)</td>
</tr>
<tr>
<td>$rrs$</td>
<td>0.69</td>
<td>Average benefits, 1st year of unemployment, per cent of real wages</td>
<td>OECD data from 2001 to 2008</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Parameter explanation</td>
<td>Source and explanation of value</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
<td>------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>( \xi )</td>
<td>0.50</td>
<td>Trade unions' negotiation power in wage bargaining</td>
<td>Equal to private-sector job creation elasticity. Means the calibration meets the Hosios condition from Hosios (1990)(^1)</td>
</tr>
<tr>
<td>( T_{\text{cost}} )</td>
<td>0.55</td>
<td>Training costs as percentage of quarterly wages for new employees</td>
<td>Silva and Toledo (2008)</td>
</tr>
<tr>
<td>( \psi_d )</td>
<td>0.01</td>
<td>Risk premium on trading in international bonds</td>
<td>Sufficient to generate stable equilibrium</td>
</tr>
<tr>
<td>( \beta )</td>
<td>0.992</td>
<td>Subjective discounting factor</td>
<td>Standard in the literature. Corresponds to an interest rate of around 3( \frac{3}{4} ) per cent per year</td>
</tr>
<tr>
<td>( H )</td>
<td>0.85</td>
<td>Degree of habit formation. Denotes the degree to which the utility of consumption today depends on consumption yesterday</td>
<td>Standard in the literature</td>
</tr>
<tr>
<td>( \mu )</td>
<td>0.4</td>
<td>Share of consumers who are credit constrained</td>
<td>Forni et. al. (2009)</td>
</tr>
<tr>
<td>( \psi )</td>
<td>0.60</td>
<td>Home bias</td>
<td>MONA database ((fmv/fcp)*100)</td>
</tr>
<tr>
<td>( \eta )</td>
<td>0.015</td>
<td>Determines how much public investment increases productivity in the production function</td>
<td>Leeper et al. (2010). Standard in the literature</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>0.33</td>
<td>Elasticity in the production function, determining the increase in output with higher input of labour</td>
<td>Gives a wage share in the model similar to that of the private non-agricultural sector in Denmark</td>
</tr>
<tr>
<td>( \delta )</td>
<td>0.025</td>
<td>Depreciation of private capital</td>
<td>Standard in the literature</td>
</tr>
<tr>
<td>( \delta_g )</td>
<td>0.025</td>
<td>Depreciation of public capital</td>
<td>Standard in the literature</td>
</tr>
<tr>
<td>( Tq )</td>
<td>2.48</td>
<td>Adjustment costs for investment</td>
<td>Schmitt-Grohé and Uribe (2006)</td>
</tr>
<tr>
<td>( \theta_p )</td>
<td>0.78</td>
<td>Calvo parameter for prices. Determines price stickiness in the economy</td>
<td>Hansen and Hansen (2007)</td>
</tr>
<tr>
<td>( \varepsilon )</td>
<td>0.6</td>
<td>Substitution elasticity for intermediate products</td>
<td>Gives a steady-state markup of 20 per cent, as in Blanchard and Gali (2010) Christoffel et al. (2009), Colciago et al. (2008) and de Walque et al. (2009)</td>
</tr>
<tr>
<td>( \theta_w )</td>
<td>0.80</td>
<td>Calvo parameter for wages for employees</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) The Hosios condition means that wage negotiation is efficient, in the sense that the firm's equilibrium value of hiring one extra employee equals the value for society, i.e. what a social planner would have done. The condition ensures that two externalities, one extra firm increasing the job creation frequency for one employee and one extra firm reducing the job creation frequency for other firms are mutually exclusive.
In addition, parameters are set determining stochastic processes, such as taxes, subsidies and government expenditure, depending on the shock and analysis. A similar calibration is applied to the euro area.

---

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter explanation</th>
<th>Source and explanation of value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_{wn}$</td>
<td>0.70</td>
<td>Calvo parameter for wages for new jobs</td>
<td>Christoffel et al. (2009)</td>
</tr>
<tr>
<td>$\tau_{ks}$</td>
<td>0.25</td>
<td>Corporate tax</td>
<td>MONA database</td>
</tr>
<tr>
<td>$\tau_{scs}$</td>
<td>0.08</td>
<td>ATP (labour-market supplementary pension)</td>
<td>MONA database</td>
</tr>
<tr>
<td>$\tau_{cs}$</td>
<td>0.25</td>
<td>VAT rate</td>
<td>MONA database</td>
</tr>
<tr>
<td>$\tau_{s}$</td>
<td>0.33</td>
<td>Tax on earned income</td>
<td>MONA database (BSDA)</td>
</tr>
<tr>
<td>$\tau_{ubs}$</td>
<td>0.34</td>
<td>Tax on return on bond investments</td>
<td>MONA database (tsuih)</td>
</tr>
</tbody>
</table>

Note: The notation is in accordance with Stähler and Thomas (2011).
This Appendix performs a robustness check of the model results to the chosen calibration. A result can be defined as robust in a calibrated DSGE-model if it holds true irrespective of the parameterisation and of the functional forms of e.g. the utility function, production function, etc., cf. e.g. Pappa (2009).

The background for this analysis is that the parameters of a calibrated DSGE model are set on the basis of information from microeconometric studies, or are directly observable. There is a reasonable amount of available information on a number of parameters, e.g. the share of government purchases of goods and services relative to GDP, which can be observed directly from the national accounts, or statutory tax rates. However, DSGE models also contain a number of parameters that are difficult to observe based on data. A case in point is the parameters in the household utility function, e.g. the parameter $h$, which determines the degree of habit formation in household private consumption, or the share of credit constrained consumers, $\mu$. Some of these unobservable parameters can be estimated using econometric analyses, although possibly with a high degree of uncertainty. This is inappropriate if the general model implications and results are greatly dependent on these more or less unobservable parameters.

However, economic theory puts certain limitations on the possible parameter scope. For example, the Calvo parameter must be positive and lower than 1, since it is a probability, and investment costs must be positive. These natural and theoretical limitations may be utilised in a robustness check. This Appendix applies a method that can be described as follows, cf. Canova (2011).

A broad interval for the model parameters is defined, in compliance with theoretical and natural limitations. A number of randomly chosen figures are drawn from a uniform distribution on this interval, and the model is recalibrated with these extracted parameters. The desired shocks are then recalculated in the model, e.g. the effect of higher government spending or higher productivity growth, and the effects on variables of interest are ranked and the 16th and 84th percentiles calculated. These two percentiles can be interpreted as uncertainty bands for the effects of the shock on the variables in relation to the model calibration. If, for example, the uncertainty bands are wide, containing both negative and positive values, the model result is not robust.

In the analysis in this Appendix, not all parameters are varied, only those associated with particularly high uncertainty, and for which no immediate information is available from e.g. the national accounts,
existing legislation, etc. Table A.2 shows the variation bands and the value in the standard calibration for these parameters. The explanation and notation behind the parameters follow Table A.1.

In the analysis, the GDP multiplier from the first stylised fiscal package described in section 3 is considered. The multiplier is recalculated 1,000 times with randomly chosen parameter values within the bands in Table A.2. The GDP multiplier is ranked according to first-quarter effects, and the 16th and 84th percentiles are calculated.

The results of the robustness check are presented in Chart B.1, left, for the GDP multiplier and Chart B.1, right, for the effect on private domestic consumption of higher government purchases of goods and services. The Charts show the effects from the standard calibration and the 16th and 84th percentiles.

### Table A.2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard calibration</th>
<th>Upper limit</th>
<th>Lower limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_p$</td>
<td>0.06</td>
<td>0.15</td>
<td>0.01</td>
</tr>
<tr>
<td>$s_g$</td>
<td>0.03</td>
<td>0.075</td>
<td>0.005</td>
</tr>
<tr>
<td>$\phi^p$</td>
<td>0.50</td>
<td>0.75</td>
<td>0.25</td>
</tr>
<tr>
<td>$\phi^g$</td>
<td>0.30</td>
<td>0.75</td>
<td>0.25</td>
</tr>
<tr>
<td>$\xi$</td>
<td>0.50</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>$\psi_d$</td>
<td>0.01</td>
<td>0.1</td>
<td>0.001</td>
</tr>
<tr>
<td>$H$</td>
<td>0.85</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>$\mu$</td>
<td>0.4</td>
<td>0.75</td>
<td>0.1</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>$\delta_g$</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>$Tq$</td>
<td>2.48</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>$\theta_p$</td>
<td>0.78</td>
<td>0.9</td>
<td>0.2</td>
</tr>
<tr>
<td>$\sigma_c$</td>
<td>2</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>$\varepsilon$</td>
<td>0.6</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>$\theta_w$</td>
<td>0.80</td>
<td>0.9</td>
<td>0.2</td>
</tr>
<tr>
<td>$\theta_{wn}$</td>
<td>0.70</td>
<td>0.9</td>
<td>0.2</td>
</tr>
</tbody>
</table>
The robustness check shows that, with a high degree of probability, the model generates a GDP multiplier greater than zero and smaller than 0.9. Similarly, there is a high degree of probability that the effect on consumption in the fiscal package is negative. This means that – given the intervals for the parameters in Table A.2 – it can be said with 68 per cent certainty that an increase in government purchases of goods and services results in decreasing domestic consumption.