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Working Paper

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ECB Working Paper, No. 2019

Provided in Cooperation with:
European Central Bank (ECB)

EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

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No 2019 / February 2017

Abstract

This paper uses two established DSGE models (QUEST III and Smets-Wouters) to assess the impact of fiscal spending cuts on output and, in particular, also on inflation in the euro area under alternative settings for monetary policy. We compare four different settings of constrained monetary policy, taking into account alternative agents' expectations about future monetary policy. We illustrate that those expectations are even more important for the size of the fiscal multipliers than the difference between exogenously versus endogenously modelled constraints. We confirm the well-known finding that fiscal multipliers exhibit an over-proportional reaction when monetary policy is constrained. The novelty of our results is that this over-proportionality is stronger for the fiscal multiplier on inflation than on output. We relate this finding to the structural parameters of the models by means of a Global Sensitivity Analysis.

Keywords: fiscal multipliers, constrained monetary policy, zero lower bound.
JEL Codes: E31, E43, E52, E62, E63.

Non-technical summary

As a consequence of rising debt-to-GDP ratios in several euro area member states, the euro area as a whole is going through a period of significant fiscal consolidation. At the same time it observes a prolonged period of low inflation combined with a binding zero lower bound (ZLB) constraint on its key policy interest rates. Despite a highly accommodative monetary policy stance and modest yet stable growth in output, the inflation rate is expected to stay low also in the near future. This ambivalent reaction of output growth and inflation has not yet been fully understood. On the one hand, a number of recent studies have shown that the impact of fiscal policies on output can be significantly different at the ZLB (see e.g. Woodford, 2011; Eggertsson, 2011; Coenen et al., 2012; Burgert and Wieland, 2013). On the other hand, considerably smaller evidence exists for the impact of fiscal measures on inflation, especially in the context of fiscal consolidation (see e.g. Orphanides and Wieland, 1998, 2000). Understanding the fiscal multiplier on output and, as a novelty, also on inflation when monetary policy is constrained, is essential for a central bank with a mandate of price stability, such as the European Central Bank.

Against this backdrop, our paper illustrates how the presence of a constrained monetary policy can alter the reaction of both output and inflation in response to a contractionary fiscal shock. We find that the non-linearities implied by the interest rate constraint exhibit strong dis-inflationary effects in response to fiscal spending cuts. In addition, we also illustrate how the modelling choice of the interest rate constraint influences the size of fiscal multipliers in structural models. What distinguishes our analysis from the majority of other studies is our focus on fiscal multipliers associated with government spending cuts rather than increases. This assumption has some bearings on the results and their interpretation. As pointed out by Erceg and Lindé (2014), a temporary fiscal stimulus at the ZLB results in an increase of the interest rate which would be implemented without a constraint (the so-called shadow interest rate) and thus shortens the period of the binding constraint. In contrast, a fiscal spending cut is likely to exert additional dis-inflationary pressure and thus to extend the constraint's duration.

In order to illustrate the relevance of different approaches to modelling the interest rate constraint, we consider four scenarios with varying key assumptions. The first two assume that the time during which the interest rate is constrained or, more precisely, fixed at the steady-state level, is exogenously given. Such an approach mimics to some extent forward guidance whereby the central bank commits to keeping its rate unchanged for a specified period of time. In the first scenario the agents fully anticipate the length of this period, reflecting full credibility of the policy announcement. In the second scenario the agents are instead continuously surprised and expect each period that the next period's interest rate will be set in line with the regular interest rate rule again. Hence, the feature that distinguishes the first two scenarios is the extent to which the length of the fixed interest rate is known to the agents. The importance of that distinction is mentioned among others by Cwik and Wieland (2011). The third and the fourth scenario investigate an alternative approach by assuming that the interest rate follows an endogenous process that can be driven to a level where the constraint becomes binding. The length of constrained monetary policy is therefore endogenously determined by the model dynamics. In the third scenario that level is below, but close to, the steady-state level of the interest rate. This mimics a situation where a central bank faces only little room to manoeuvre due to the presence of an endogenous lower-bound constraint. Moreover, it is practical to set the lower bound near the steady state as a fiscal shock of one percent of GDP is not large enough to drive the economy, which is initially at the steady state, to the zero lower bound. In fact, in the models considered in our paper, it would require a fiscal spending cut of more than 50 percent of GDP for the zero lower bound to become relevant. For this reason, in the fourth scenario we add a negative demand crisis shock that precedes the fiscal spending cut such that the economy is already at the zero lower bound when the fiscal shock occurs.

To measure the immediate impact of a fiscal spending shock on both output and inflation, we define an instantaneous multiplier as a percentage deviation of a measured variable from its steady state in the first period following a fiscal spending shock of a size of one percent of GDP. In turn, the long-run impact is measured by means of a cumulative multiplier. To set up the latter, we adapt the definition of Uhlig (2010) and we extend it into a broader context. However, the most interesting measure highlighted in our analysis is the relative multiplier, defined as a ratio between the multipliers obtained under constrained monetary policy and when monetary policy is active.

Four key results emerge. It is well known that the fiscal multipliers at constant interest rates can be large. We show, however, that, first of all, this result is largely determined by the agents' expectations about future monetary policy. For example, the fiscal multiplier on output when the monetary policy is fully anticipated can be two times larger as compared to the multiplier obtained under an unanticipated scenario. Second, we show that the relative multipliers for output and inflation exhibit strong non-linearities with the length of the binding constraint. For the output multiplier this result is well analysed in other model comparison exercises as in Cogan et al. (2010). The novel finding in our paper highlights that this non-linearity is stronger for inflation than for output. For example, when monetary policy is constrained for twelve quarters, the fiscal multiplier on inflation can become six times larger as compared to the scenario where monetary policy is active. The same relative multiplier for output is only about two. Third, we also find that the endogenously-driven interest rate constraint at the zero lower bound generates somewhat larger multipliers as compared to a scenario where it is imposed exogenously, in particular for the fiscal multiplier on inflation. Nevertheless, the difference in the size of multipliers obtained in these two approaches is smaller as compared to the difference stemming from different assumptions about the agents' expectations of future monetary policy. Finally, our simulations show that the instantaneous multiplier is only useful when the duration of constrained monetary policy is anticipated, which is in line with the findings of Uhlig (2010). If it is unanticipated then the cumulative multiplier becomes much more informative. As agents acquire the information about the duration of the constraint only successively over time, such a process is better captured by the cumulative concept.

Finally, in order to understand the novel finding of an over-proportional deflationary impact of fiscal consolidation with constrained monetary policy, we conduct a Global Sensitivity Analysis (GSA). For that purpose, we look at which structural parameters drive the difference between the multipliers on inflation and on output for selected scenarios. We find that the over-proportional deflationary effect is driven by higher real production frictions, lower nominal production frictions, a higher persistence in the fiscal spending cut and a larger coefficient on inflation in the central bank's interest rate rule.

I. Introduction

As a consequence of rising debt-to-GDP ratios in several euro area member states, the euro area as a whole is going through a period of significant fiscal consolidation. At the same time it observes a prolonged period of low inflation combined with a binding zero lower bound (ZLB) constraint on its key policy interest rates. Despite a highly accommodative monetary policy stance and modest yet stable growth in output, the inflation rate is expected to stay low also in the near future. This ambivalent reaction of output growth and inflation has not yet been fully understood. On the one hand, a number of recent studies have shown that the impact of fiscal policies on output can be significantly different at the ZLB (see e.g. Woodford, 2011; Eggertsson, 2011; Coenen et al., 2012; Burgert and Wieland, 2013). On the other hand, considerably smaller evidence exists for the impact of fiscal measures on inflation, especially in the context of fiscal consolidation (see e.g. Orphanides and Wieland, 1998, 2000). Understanding the fiscal multiplier on output and, as a novelty, also on inflation when monetary policy is constrained, is essential for a central bank with a mandate of price stability, such as the European Central Bank.

Against this backdrop, our paper illustrates how the presence of monetary policy constraints can alter the reaction of both output and inflation in response to a contractionary fiscal shock. We find that the non-linearities implied by the interest rate constraint exhibit strong dis-inflationary effects in response to fiscal spending cuts. In addition, we also illustrate how the modelling choice of the interest rate constraint influences the size of fiscal multipliers in structural models. To this aim, we conduct a comparative analysis that looks at the impact of a contractionary fiscal spending shock under different assumptions for the constrained monetary policy. For our analysis we employ two well-known dynamic stochastic general equilibrium (DSGE) models for the euro area: QUEST III of the European Commission (Ratto et al., 2009) and the Smets-Wouters model developed at the European Central Bank (Smets and Wouters, 2003). Both of them are available in the Macroeconomic Model Data Base (MMB) by Wieland et al. (2012) in their estimated version. We work with the models specified above because they are widely used in academia and for policy advice, and because, as estimated models, they allow us to generate both qualitative and quantitative results. Moreover, their relatively rich structure enables us to relate our findings to the models' structural parameters, which enhances the interpretation of the results. Yet, the size of these models is not too large, which allows us to utilise a DYNARE toolkit of Guerrieri and Iacoviello (2015) for solving DSGE models with occasionally binding constraints.

Our paper contributes to the literature in two ways. First, by illustrating that the non-linear effects stemming from government spending cuts when monetary policy is constrained are larger on inflation than on output. Second, by highlighting the importance of the modelling choices to capture the constraint. While, to the best of our knowledge, the former is a novelty, the latter has been already partially studied. For example, Siemens and Watzka (2013) compare the results of two influential papers, Cogan et al. (2010) versus Christiano et al. (2011), that give two contrary messages about the size of fiscal multipliers at the zero lower bound. Cogan et al. (2010) show that the fiscal multipliers are only slightly above unity if the ZLB is binding, while Christiano et al. (2011) claim that, under the same assumption, the multipliers can be significantly larger than one. When looking closely at the underlying simulations, Siemens and Watzka (2013) notice that in Cogan et al. (2010) the interest rates are set to zero following a deterministic process whereby the rates remain at the zero level even though the Taylor-rule-implied interest rate is positive. In contrast to this exogenous constraint, Christiano et al. (2011) model the ZLB as an endogenous reaction of the central bank to a negative demand shock. Therefore, Siemens and Watzka (2013) claim that the differences in multipliers obtained in these two studies arise mainly from the modelling of the zero lower bound. In our paper, we extend the analysis of different implementations of the interest rate constraint combining the "exogenous" and "endogenous" settings with different assumptions about the agents' expectations of future monetary policy. We find that the exogenous approach generates somewhat different multipliers as compared to the endogenous implementation. However, the differences are not large enough to justify the claim of Siemens and Watzka (2013). In turn, our findings illustrate that it is the modelling of agents' expectations about future monetary policy that is key for determining the size of fiscal multipliers.

What distinguishes our analysis from the above-mentioned studies is our focus on fiscal multipliers associated with government spending cuts rather than increases.[1] This assumption has some bearings on the results and their interpretation. As pointed out by Erceg and Lindé (2014), a temporary fiscal stimulus at the ZLB results in an increase of the interest rate which would be implemented without a constraint (the so-called shadow interest rate) and thus shortens the period of the binding constraint. In contrast, a fiscal spending cut is likely to exert additional dis-inflationary pressure and thus to extend the constraint's duration. We show that this asymmetrical behaviour restricts the analysis of fiscal spending cuts at the ZLB to the "endogenous" set-up only. When modelling the ZLB via an exogenous constraint, a fiscal spending cut may require the interest rate to fall below zero once

[1] Other interesting fiscal spending plans at the ZLB, such as a fiscal stimulus financed with prospective fiscal spending cuts as in Corsetti et al. (2010), are beyond the scope of this paper.

the constraint ceases to bind, which is inconsistent with the very nature of the constraint. Therefore, the “exogenous” constraint should be considered as a choice by policy-makers.

In order to illustrate the relevance of different approaches to modelling the interest rate constraint, we consider four scenarios with varying key assumptions. The first two assume that the time during which the interest rate is constrained or, more precisely, fixed at the steady-state level, is exogenously given. Such an approach mimics to some extent forward guidance whereby the central bank commits to keeping its rate unchanged for a specified period of time. In the first scenario the agents fully anticipate the length of this period, reflecting full credibility of the policy announcement. In the second scenario the agents are instead continuously surprised and expect each period that the next period’s interest rate will be set in line with the regular interest rate rule again. Hence, the feature that distinguishes the first two scenarios is the extent to which the length of the fixed interest rate is known to the agents. The importance of that distinction is mentioned among others by Cwik and Wieland (2011). The third and the fourth scenario investigate an alternative approach by assuming that the interest rate follows an endogenous process that can be driven to a level where the constraint becomes binding. The length of constrained monetary policy is therefore endogenously determined by the model dynamics. In the third scenario that level is below, but close to, the steady-state level of the interest rate. This mimics a situation where a central bank faces only little room to manoeuvre due to the presence of an endogenous lower-bound constraint. Moreover, it is practical to set the lower bound near the steady state as a fiscal shock of one percent of GDP is not large enough to drive the economy, which is initially at the steady state, to the zero lower bound. In fact, in the models considered in our paper, it would require a fiscal spending cut of more than 50 percent of GDP for the zero lower bound to become relevant. For this reason, in the fourth scenario we add a negative demand crisis shock that precedes the fiscal spending cut such that the economy is already at the zero lower bound when the fiscal shock occurs.

To measure the immediate impact of a fiscal spending shock on both output and inflation, we define an instantaneous multiplier as a percentage deviation of a measured variable from its steady state in the first period following a fiscal spending shock of a size of one percent of GDP. In turn, the long-run impact is measured by means of a cumulative multiplier. To set up the latter, we adapt the definition of Uhlig (2010) and we extend it into a broader context. However, the most interesting measure highlighted in our analysis is the relative multiplier, defined as a ratio between the multipliers obtained under constrained monetary policy and when monetary policy is active.

Four key results emerge. It is well known that the fiscal multipliers at constant interest rates can be large. We show, however, that, first of all, this result is largely determined by the agents' expectations about future monetary policy. For example, the fiscal multiplier on output when the monetary policy is fully anticipated can be two times larger as compared to the multiplier obtained under an unanticipated scenario. Second, we show that the relative multipliers for output and inflation exhibit strong non-linearities with the length of the binding constraint. For the output multiplier this result is well analysed in other model comparison exercises as in Cogan et al. (2010). The novel finding in our paper highlights that this non-linearity is stronger for inflation than for output. For example, when monetary policy is constrained for twelve quarters, the fiscal multiplier on inflation can become six times larger as compared to the scenario where monetary policy is active. The same relative multiplier for output is only about two. Third, we also find that the endogenously-driven interest rate constraint at the zero lower bound generates somewhat larger multipliers as compared to a scenario where it is imposed exogenously, in particular for the fiscal multiplier on inflation. Nevertheless, the difference in the size of multipliers obtained in these two approaches is smaller as compared to the difference stemming from different assumptions about the agents' expectations of future monetary policy. Finally, our simulations show that the instantaneous multiplier is only useful when the duration of constrained monetary policy is anticipated, which is in line with the findings of Uhlig (2010). If it is unanticipated then the cumulative multiplier becomes much more informative. As agents acquire the information about the duration of the constraint only successively over time, such a process is better captured by the cumulative concept.

Finally, in order to understand the novel finding of an over-proportional deflationary impact of fiscal consolidation with constrained monetary policy, we conduct a Global Sensitivity Analysis (GSA). For that purpose, we look at which structural parameters drive the difference between the multipliers on inflation and on output for selected scenarios. We find that the over-proportional deflationary effect is driven by higher real production frictions, lower nominal production frictions, a higher persistence in the fiscal spending cut and a larger coefficient on inflation in the central bank's interest rate rule.

The remaining sections of this paper are structured as follows. Sections II and III describe in more detail our definition of constrained monetary policy as well as the instantaneous and cumulative multipliers. Section IV provides an overview of the models. The results of our analysis are presented and discussed in Section V. The Global Sensitivity Analysis is conducted in Section VI. Finally, Section VII concludes with some closing remarks.

II. Modelling the interest rate constraint

How the interest rate constraint is modelled is essential for the size of fiscal multipliers. Therefore, we carefully explain our approach and set the ground for further analysis in this section. We describe the simulation scenarios and provide some guidance for their interpretation. As our aim is to conduct a comparative analysis, we construct the scenarios in a way that allows us to highlight the importance of certain modelling assumptions. With this goal in mind, we extend the focus of our analysis beyond the zero lower bound constraint and look at a broader concept of an interest rate constraint. Indeed, it is well known in the literature that the fiscal multiplier on output increases when monetary policy hits its zero lower bound constraint. In fact, such a finding applies to a broader standpoint of monetary policy. Monetary policy can be constrained either by policy choice (e.g. "forward guidance") or it can be restricted due to a binding constraint. Consequently, throughout this paper we do not distinguish between these two situations but simply refer to them jointly as "constrained" monetary policy.

There are several approaches for implementing such a policy stance in structural models. Constrained monetary policy can be modelled by assuming that the interest rate is exogenously fixed at a certain level or the constraint can derive from an endogenous rule. A key difference between these two situations pertains to a determination of the period during which monetary policy does not respond to shocks that require stabilisation of the output gap and inflation. In the case of the exogenously-imposed constraint, the duration is chosen by a modeller, while in the case of an endogenous constraint the length of the binding constraint is determined by model dynamics. In practice, when modelling the exogenously-fixed interest rate, it is usually assumed that it remains at the steady state for a period of about two to three years and afterwards is allowed to float. Such a choice is often dictated by practical considerations as DSGE models might not solve if the constraint binds for a longer period of time. In the case of an endogenously-driven constraint, in turn, the modeller chooses a value of the lower bound (usually it is the zero lower bound but in fact it can be any value below the steady state) and the length for which the constraint is binding is endogenously determined by a shadow interest rate rule. The shadow rule allows the interest rate to enter the territory below the specified value and signals the period of a binding constraint until the (shadow) interest rate rises again above this value.

Unsurprisingly, such a different implementation of the interest rate constraint is also likely to influence the size of fiscal multipliers depending on whether the fiscal policy is contractionary or expansionary. In particular, a fiscal spending cut when accompanied by an endogenous interest rate constraint (say, the zero lower bound) extends the duration of the constraint. A fiscal stimulus in the same environment results in an increase of the shadow interest rate and thus shortens the period of the binding constraint (see e.g. Erceg and Lindé, 2014). As a consequence, the corresponding multipliers will differ. This is, however, not necessarily the case for exogenously-imposed constraints. When the constraint is set at the zero level, the multipliers associated with spending cuts cannot be correctly computed, at least not for all sizes of the fiscal shock. As the negative spending shock depresses output and inflation, the interest rate may be required to drop below zero once the exogenously-determined ZLB ceases to bind such that the model returns to the equilibrium. This is obviously inconsistent with the very nature of the constraint. This feature is usually overlooked in the literature as the majority of studies focuses on fiscal expansion where the positive spending shock results in an increase of the interest rate, which does not violate the constraint. We illustrate this point by setting the exogenous constraint at the steady-state level and simulating the fiscal spending cut of one percent of GDP for various lengths of the constraint. As the results below show, once the constraint ceases to bind, the interest rate falls below the steady-state level in response to the negative fiscal shock.

One possible "work-around" that would enable the analysis of fiscal spending cuts at the "exogenous" zero lower bound could be to scrap the original law of motion for the government spending shock. One could then consider scenarios where government spending is reduced by one percent of GDP for the minimum number of quarters for which the policy rate can be kept fixed without declining after the lift-off. Such a solution would, however, hinder a comparability of our scenarios as the calculated multipliers would be associated with different shock schedules. This, in addition, would make the concept of the cumulative multiplier meaningless. We therefore refrain from implementing this solution. Instead we focus on constrained monetary policy with the exogenous bound set to the steady-state value. Such a scenario does not only fulfil our requirement of comparability but also has a meaningful interpretation, i.e. it can be seen as forward guidance whereby the central bank commits to keeping the interest rate at a certain level for a pre-announced period of time. The exogenously-imposed constraint at the steady state can be applied to study both government spending cuts and increases as it is conceivable to assume that the central bank decides to keep the rates unchanged either in a spending stimulus or spending cut situation. Once the constrain ceases to bind, the rates can then be allowed to float in any direction, i.e. become either higher or lower than the steady-state value.

In addition, we show that the modelling of agents' expectations about future interest rates is fundamental for determining the size of fiscal multipliers. In a stochastic simulation three types of expectations regarding the future reaction of monetary policy can be distinguished. First, agents can fully anticipate the future monetary policy stance. In particular, they know the length of the period during which it will be constrained. Second, agents do not anticipate future interest rates correctly and are continuously surprised. During the times of a binding constraint, the agents may expect each period that the next period's interest rate will float again. Third, a solution that somehow bridges these two extreme behaviours assumes learning expectations whereby the agents are initially surprised but as the shock unfolds they learn about its duration. Dieppe et al. (2013) show for a large structural model for the euro area that such an approach converges in the long run to the "anticipated" solution. Modelling learning expectations is not a trivial task, though, and in the absence of commonly available DSGE models with learning-type of expectations an analysis thereof is outside the scope of this paper. For that reason in the remaining parts of the paper we illustrate the two extreme cases only: the case of fully anticipated monetary policy and the case where each period the agents are surprised about the monetary policy stance.

Moreover, when modelling the ZLB by means of an endogenous interest rate constraint, it is important to account for the initial state of the economy that is subject to a fiscal spending shock. An economy that is in the steady state would require an unrealistically large fiscal spending cut in order for the interest rate to reach the zero level. In practice, this modelling issue is circumvented by an assumption that a fiscal shock is preceded by a negative demand shock (see e.g. Erceg and Lindé, 2011; Coenen et al., 2012; Schwarzmüller and Wolters, 2014). The negative demand shock does indeed drive the interest rate to the ZLB (or close to it) but at the same time it is associated with a certain duration of the binding constraint. The initial state of the economy and the choice of the size of the demand shock are therefore very relevant. We illustrate this in two types of simulations. First, we model the interest rate constraint by imposing a lower bound to be a value below, but close to, the steady state. The sensitivity analysis around this value shows that the more room the central bank has to manoeuvre prior to hitting the constraint, the smaller the multipliers. Second, we simulate a negative demand shock that is followed by a fiscal spending cut. In such a set-up, the impact of the fiscal shock can be inferred from the difference of the "crisis-only" scenario and the combined "crisis-and-fiscal-shock" scenario. A sensitivity analysis around the parameter governing the demand shock confirms that the stronger the shock, the larger the multipliers.

Summing up, the scenarios of constrained monetary policy we look at in this paper are:

Scenario 1: An exogenously-imposed period of fixed interest rates combined with fully anticipated monetary policy, i.e. the interest rate is kept at the steady state for an announced period of time and the agents perceive this announcement as fully credible. In this scenario the type of the fiscal shock (consolidation vs stimulus) does not play a role, i.e. the effects of the interest rate constraint can be interpreted symmetrically. Note that this scenario does not refer to the zero lower bound case but to a situation in which the central bank decides to keep its rates unchanged.

Scenario 2: An exogenously-imposed period of fixed interest rates combined with unanticipated monetary policy, i.e. the interest rate is kept at the steady state for an unannounced period of time. Thus, each period agents are surprised that the interest rate is fixed and they expect it to float from the next period onwards. In this scenario the type of the fiscal shock (consolidation vs stimulus) does not play a role, i.e. the effects of the interest rate constraint can be interpreted symmetrically. As in the previous scenario, note that this scenario does not refer to the zero lower bound case but to a situation in which the central bank decides to keep the rates unchanged.

Scenario 3: An endogenously-driven lower bound at a level below, but close to, the steady state. It conforms to a hypothetical situation whereby the central bank announces a lower bound (not necessarily zero) for its interest rate. The time period of a binding constraint is determined endogenously by the system. In this scenario the results only hold for shocks that require lower interest rates, i.e. fiscal spending cuts.

Scenario 4: An endogenously-driven zero lower bound. In nature, it is the same as the third scenario. Yet, given that it would require a huge fiscal spending cut alone to reach the zero lower bound, we look at a spending cut that is preceded by a negative demand shock which brings the economy to the zero lower bound. In this scenario the effects of the interest rate constraint are asymmetric as a cut in government spending prolongs the period during which the constraint is binding, whereas an increase in government spending can reduce it.

III. Definition of the fiscal multipliers

In order to differentiate between the immediate impact of a change in fiscal spending and its long-run implications for the economy, we define an instantaneous and a cumulative fiscal multiplier. In defining the cumulative multiplier we follow Uhlig (2010). His definition is common in the literature, see e.g. Coenen et al. (2012). Given that these multipliers refer solely to output, we extend the definition more broadly.

Definition: *The* instantaneous fiscal multiplier *measures in each period the percentage deviation of a variable from its steady state in response to a change in government spending that in the initial period amounts to one percent of output.*

In formal terms, let hats denote the percentage deviation of a variable from its own steady state (denoted by a bar) in period t. That is, in each period variable X_t is transformed to $\widehat{x}_t = \frac{X_t - \overline{X}}{\overline{X}}$. Denoting output and government spending as Y_t and G_t respectively, the instantaneous fiscal multiplier on output is defined as:

$$\phi_t(\widehat{y}) \equiv \frac{\widehat{y}_t}{\widehat{g}_T \frac{\overline{G}}{\overline{Y}}}, \forall t \geq T \tag{1}$$

where t is the time index for the periods following the initial fiscal shock in period T. Similarly, the definition of the instantaneous fiscal multiplier on inflation Π_t is given by:

$$\phi_t(\widehat{\pi}) \equiv \frac{\widehat{\pi}_t}{\widehat{g}_T \frac{\overline{G}}{\overline{Y}}}, \forall t \geq T \tag{2}$$

Thus, ϕ_t tells us the immediate impact of the fiscal spending change on the respective variable (for $t = T$) and also the impact on future periods (for $t > T$). Periods shortly after the fiscal shock might be of particular interest if the variable's response is u-shaped. Even though the initial multiplier might be small it could still be possible that the instantaneous multiplier reaches a considerable peak later on. For a policy maker the level and timing of the peak might be of similar interest as the initial impact.

The discussion makes one flaw of the instantaneous multiplier obvious. As put forward by Uhlig (2010), solely relying on the instantaneous multiplier can be misleading as it ignores the cumulated impact of the initial fiscal policy measure on the economy over time. This applies also to the change in government spending itself. Fiscal policies are rarely one-period measures, but are usually conducted over time. In the DSGE literature, fiscal shocks are commonly designed as AR(1) processes. Thus, even though the largest effects of a fiscal change are on impact, it might have very long-lasting fallouts, depending on the autoregressive coefficient. In order to relate the cumulative impact on the variable of interest to the cumulative fiscal shock, we define a cumulative fiscal multiplier in analogy to Uhlig (2010).

Definition: *The* cumulative fiscal multiplier *measures up to each period the discounted cumulative change of a variable measured in percentage deviation from its steady state relative to the discounted cumulative change in government spending from its steady state.*

In the case of output, discounting is a straightforward notion. It implies that the cumulative multiplier relates the net present value of all changes in output to the net present value of the fiscal shock. Let us define the discount rate as $\overline{R}$. Then, the cumulative fiscal multiplier on output in technical terms is given by:

$$\Phi_t(\widehat{y}) \equiv \frac{\sum_{s=T}^{t} \overline{R}^{-(s-T)} \widehat{y}_s}{\frac{\overline{G}}{\overline{Y}} \sum_{s=T}^{t} \overline{R}^{-(s-T)} \widehat{g}_s} = \widehat{g}_T \frac{\sum_{s=T}^{t} \overline{R}^{-(s-T)} \phi_s(\widehat{y})}{\sum_{s=T}^{t} \overline{R}^{-(s-T)} \widehat{g}_s}, \forall t \geq T \tag{3}$$

Whereas the discount rate can be justified by an opportunity cost argument from finance, one can also derive it from a micro-founded preference argument. The latter is especially appealing as it helps to justify why the inflation rate should also be discounted in the same fashion, despite the fact that there is no such notion as a net present value of inflation. Why should an economic agent bother whether inflation happens now or in the future if all prices move in line with the inflation rate? In real terms the agent would be indifferent. The answer is provided by the time preference. Agents prefer to handle issues immediately instead of postponing them to the future. The farther apart the issue, the less attention it obtains. To illustrate this point, imagine a policy-maker with a time preference of $\beta \in (0, 1]$ who observes an aggregate shock to the economy in period T, yet she can freely decide how to distribute the aggregate shock over the coming periods. If the objective of the policy-maker is to stabilise output and inflation deviations around the steady state, she would formally solve (with $\widetilde{y}$ and $\widetilde{\pi}$ being the aggregate shocks):[2]

$$\min_{\{\widehat{y}_s, \widehat{\pi}_s\}_{s \geq T}} \sum_{s=T}^{\infty} \beta^{s-T} (\widehat{y}_s^2 + \widehat{\pi}_s^2) \text{ s.t.} \sum_{s=T}^{\infty} \widehat{y}_s = \widetilde{y} \text{ and} \sum_{s=T}^{\infty} \widehat{\pi}_s = \widetilde{\pi} \tag{4}$$

Optimality implies that the paths for output and inflation fulfil: $\widehat{y}_t = \beta \widehat{y}_{t+1}$and $\widehat{\pi}_t = \beta \widehat{\pi}_{t+1}$. Thus, when defining a cumulative multiplier it makes sense to reduce the impact of future values relative to current values due to the time preference of agents. As well-known from the DSGE literature, the time preference equals the inverse of the steady state gross interest rate. Denoting the latter by $\overline{R}$, we get $\beta = \overline{R}^{-1}$. The cumulative multiplier on output can

[2]The optimisation is a highly stylised thought experiment in order to illustrate the point. The dynamics describing the economy are not part of it and thus there is no trade-off (such as presented by the Phillips curve) in shifting output and inflation around.

therefore be applied to the inflation rate one to one:

$$\Phi_t(\widehat{\pi}) \equiv \frac{\sum_{s=T}^{t} \overline{R}^{-(s-T)} \widehat{\pi}_s}{\frac{\overline{G}}{\overline{Y}} \sum_{s=T}^{t} \overline{R}^{-(s-T)} \widehat{g}_s} = \widehat{g}_T \frac{\sum_{s=T}^{t} \overline{R}^{-(s-T)} \phi_s(\widehat{\pi})}{\sum_{s=T}^{t} \overline{R}^{-(s-T)} \widehat{g}_s}, \forall t \geq T \tag{5}$$

Concerning the terminology, the numerator could be interpreted as the net present value of inflation costs.

In order to understand the relation between the instantaneous and cumulative multipliers, a closer look at the structure of fiscal shocks becomes necessary. In the DSGE literature, fiscal spending shocks are usually implemented as an AR(1) process of the form $\widehat{g}_s = \rho \widehat{g}_{s-1} + \varepsilon_s$ where the AR coefficient ρ measures the persistence of the fiscal policy and ε_s is the actual shock. If we assume that the surprising element of the fiscal spending change happens only once in period T ($\varepsilon_T \neq 0$) and the economy was initially in the steady state ($\widehat{g}_{T-1} = 0$), it follows that $\widehat{g}_s = \rho^{s-T} \varepsilon_{T,} \forall s \geq T$. Using this expression for the cumulative fiscal multiplier for a generic variable $\widehat{x}$ and setting $T = 0$ without loss of generality, equations (3) and (5) can be written as:

$$\Phi_t(\widehat{x}) = \frac{\sum_{s=0}^{t} \left(\frac{\phi_s(\widehat{x})^{\frac{1}{s}}}{\overline{R}}\right)^s}{\sum_{s=0}^{t} \left(\frac{\rho}{\overline{R}}\right)^s}, \forall t \geq 0 \tag{6}$$

Equation (6) reveals the conditions that determine the size of cumulative fiscal multipliers. Firstly, it becomes apparent that in a linear model the size of the fiscal shock does not have any impact on the cumulative multiplier as the relative response of output, measured by the instantaneous multiplier ϕ_s, is constant for any size of the shock. In non-linear models, however, the size of the fiscal shock does influence the size of cumulative multipliers. Secondly, the persistence ρ of the fiscal shock is a key factor in determining the size of the cumulative fiscal multiplier as it has direct effects on Φ_t. Since $\overline{R} > 1$ and $\rho \in (0, 1)$, the persistence determines how fast the terms of the sum in the denominator approach zero. Thus, the value of Φ_∞ depends to a large extent on whether the instantaneous multiplier fades out faster than ρ. Given that ϕ_s also depends on ρ and given the complexity of the models, the only way to obtain results for the multipliers is by means of simulations. Yet, one can already speculate at this point that variables which show a higher degree of persistence will have a slower fading out instantaneous multiplier and thus show a larger cumulative multiplier.

Finally, for each concept – instantaneous and cumulative – let us define the *relative fiscal multiplier* as a ratio between the multipliers obtained under constrained monetary policy and when monetary policy is active. For the instantaneous multipliers the ratio refers to the peak (ϕ_{peak}) while in the case of the cumulative multipliers it corresponds to the limiting value as t approaches infinity (Φ_∞). Both the peak and limit bear the most important information of the respective multiplier.

IV. Overview of the models used

The analysis conducted in this paper is based on two well-known DSGE models for the euro area: QUEST III of the European Commission (Ratto et al., 2009) and the Smets-Wouters model developed at the European Central Bank (Smets and Wouters, 2003). Both of them are available in the Macroeconomic Model Data Base (MMB) by Wieland et al. (2012) in their estimated versions. In line with the naming convention adopted in the MMB we refer to the QUEST III model as QUEST III and to the Smets-Wouters model as SW03. Both models feature households, firms and a public sector including the fiscal government and monetary policy. In order to make the simulation results across the models more comparable, we replace the model-specific interest rate rule with a common rule. Both the common interest rate rule and the models' main features, as relevant for our analysis, are described bellow.

We work with these models as they are not only widely used in academia and for policy advice but also allow us to generate the best possible qualitative and quantitative results in terms of the empirical validity of the models. Moreover, our choice to revert to the Macroeconomic Model Data Base is motivated by the fact that MMB models went through a thorough process of model comparison by making the models run in a variety of simulations and policy analyses. We follow the MMB and focus our analysis at *common comparable variables* which are defined based on the model-specific variables such that they can be compared across models. Thus, even though both models are stated in quarterly terms, we consider the annualised percentage deviation of the interest rate from its steady state as the monetary policy instrument. Consequently, in all figures presented in the paper we show the interest rates expressed as annualised levels in percent. Moreover, for the fiscal multiplier on output we look at the output gap which is defined as the quarterly percentage deviation of output from its potential. The reason for that is not only that the QUEST III model does not have a properly defined output (only the output gap), but also that the economically more relevant variable is the output gap. Finally, for the fiscal multiplier on inflation we look at the annual percentage deviation of inflation from its steady state (i.e. the central bank's inflation target). We implement the different monetary policy constraints by means of the OccBin Toolbox of Guerrieri and Iacoviello (2015) in Dynare (see Adjemian et al., 2011).

With models that feature forward-looking agents, it is not only important how the monetary policy constraint is implemented, but also how monetary policy is conducted once the constraint ceases to be binding. Therefore, in order to increase the comparability between the two models, we use the same interest rate rule in both models. More specifically, we use the Taylor rule augmented with smoothing:

$$i_t^* = \rho_i i_{t-1} + (1-\rho_i)[\phi_\pi \widehat{\pi}_t + \phi_y \widehat{y}_t] \tag{7}$$

where i_t^* resembles the shadow interest rate, which the central bank would implement if it was not constrained in any form. The actual interest rate then equals $i_t = \max\{i_{ss}\alpha_t, i_t^*\}$ with i_{ss} being the steady-state value of the interest rate and α_t determining the constraint. For the scenarios where the interest rate is exogenously constrained, we set $\alpha_t = 1$ for $t = 1...T$ and $\alpha_t = 0$ thereafter. In the scenarios with a lower bound close to the steady state, we set $\alpha_t = \alpha \in (0, 1)$ for all t. Finally, the zero lower bound is implemented with $\alpha_t = 0$ for all t. We motivate the fact that in equation (7) the lagged actual interest rate enters on the right-hand side by the assumption that central bank eventually wants to smooth the actual interest rate and not some theoretically constructed shadow rate. However, the literature seems to have changing views on that (see e.g. Taylor and Williams, 2010). The baseline parameter values are $\rho_i = 0.9, \phi_\pi = 1.5$, and $\phi_y = 0.5$. The latter two coefficients are the original values from Taylor (1993). The high persistence is set in line with empirical literature (see e.g. Smets and Wouters, 2003). All three parameters will be part of the sensitivity analysis which will show the importance of such a choice.

i. Key features of the Smets-Wouters model

SW03 is a medium-scale closed economy DSGE model with various frictions, nominal and real. It has been developed under rigorous microeconomic foundations derived from optimisation behaviour of economic agents (households and firms). A detailed description of the model is provided in Smets and Wouters (2003).

There is a continuum of households that maximise their lifetime utility subject to an intertemporal budget constraint. The utility function is separable in consumption, leisure and real money balances. An external habit formation is present and links the habit stock to the past consumption. Each household has a monopoly power over its labour supply, so they act as price-setters in the labour market. The wage-setting follows the Calvo model adjusted by an assumption that wages are partially indexed to the past inflation. The aggregate nominal wage is then obtained by applying Dixit-Stiglitz-type of aggregator. The estimated value of the Calvo parameter is 0.76 implying an average duration of wages of about one year. Households own a capital stock which they rent to firms. They can increase the supply of rental services by either increasing the capital stock, which takes one period to be built, or by changing the utilisation rate of the already installed capital. Both actions are associated with some adjustment costs. In addition, households also hold their financial wealth in the form of cash balances and one-period risk-less bonds. Their total income therefore consists of three sources: labour income, the net cash flow from state-contingent securities holdings, and the return on the real capital stock minus the costs associated with variations in the capital utilisation plus dividends.

There is a continuum of intermediate firms that produce differentiated goods using a production function with Cobb-Douglas technology. Each intermediate firm has market power for its own goods and maximises expected profits. Intermediate firms are allowed to change their price following a Calvo scheme which has additionally been adjusted to introduce partial indexation to past inflation. The estimated Calvo parameter is 0.91 implying an average duration of prices to be about three years. The intermediate goods are then sold to the final-goods sector that acts under perfect competition and produces the final goods by means of the Dixit-Stiglitz aggregator. The final goods are used for consumption and investment by the households and by the government.

Finally, the government sector in SW03 takes a simplified form where fiscal spending is introduced exogenously by means of a first-order autoregressive process with a white noise normal error term.

ii. Key features of the QUEST III model

Turning now to QUEST III, it has been developed at the European Commission (DG-ECFN) and shares a number of common features with SW03. At the same time, being a later generation of DSGE models as compared to SW03, it has a richer structure. The main differences vis-à-vis SW03, relevant for our analysis, can be summarised as follows. As opposed to SW03, QUEST III is an open-economy model and features financial frictions in terms of liquidity-constraint households. The model has also a richer fiscal block that incorporates fiscal policy rules for government consumption, investment, transfers and wage taxes. A detailed description of the model is provided in Ratto et al. (2009).

The two types of households possess the same utility function, non-separable in consumption and leisure with habit persistence in both consumption and leisure. Liquidity-constrained households do not optimise, they just consume their labour income. Non-liquidity-constrained households have access to assets denominated in domestic and foreign currency, accumulate capital subject to investment adjustment costs and rent it to firms, earn profits from owning the firms and pay taxes. Another distinguishable feature not present in SW03 is the modelling of income from foreign financial assets where the risk premium stemming from an external financial intermediation has been added. An equity risk premium is also applied to real asset holdings. In terms of nominal rigidities, the wage setting in QUEST III also differs from SW03. In the former, the wages process is subject to a wage mark-up and to slow adjustments in the real consumption wage. The wage mark-up arises because of wage adjustment costs and the fact that a part of workers index the growth rate of wages to the past inflation. Likewise, the price setting process in QUEST III varies from the SW03 approach.

There is a finite number of monopolistically competitive final goods producers. The firms determine labour input, capital services, and set prices given demand conditions. The domestic firms sell to domestic households, investment goods producers, exporting firms and to the government. Output is produced with a Cobb-Douglas production function. The objective of the firms is to maximise the present discounted value of profits, subject to technological and regulatory constraints that introduce additional adjustment costs. In addition to the costs associated with the utilisation of capital, the firms in QUEST III are faced with a number of additional adjustment costs, e.g. costs of adjusting labour, that interfere with their price setting decisions. The aggregate price mark-up derives from the optimisation behaviour whereby firms equate the marginal product of labour, net of marginal adjustment costs, to wage costs, the marginal value product of capital to the rental price of capital, and the marginal product of capital services to the marginal cost of increasing capacity. The average mark-up is thus equal to the inverse of the price elasticity of demand. In addition, a backward looking element is introduced in which a fraction of firms index their prices to the past inflation.

Finally, rules are specified for government consumption and investment, which are allowed to deviate from the long-run targets in response to the fluctuation in the output gap. Transfers act as automatic stabilisers, providing benefits for unemployed and pensioners. Revenues come from taxes on consumption, capital, and labour income.

V. Simulation results

Having defined the instantaneous fiscal multiplier ϕ_t and the cumulative fiscal multiplier Φ_t in Section III, we can now turn to the analysis of the effects of fiscal spending cuts on output and inflation. In what follows we combine a negative fiscal shock with four different scenarios of constrained monetary policy, as described in Section II, and look at the implications of the interest rate constraint on the size of fiscal multipliers.

Figures 1- 8 illustrate the effects of a fiscal spending cut of the size of one percent of GDP. As discussed in Section III, the size of the fiscal shock is important due to the non-linearity introduced by constrained monetary policy. In that respect, our choice to set the size to one percent of GDP is somewhat arbitrary, albeit plausible, especially in the context of ensuring comparability between the two models and to the literature. Nonetheless, the shock size will be subject to the sensitivity analysis together with other parameters, presented below. Figures 1-8 all have the same pattern: the first row shows the instantaneous multipliers and the second row refers to the cumulative multipliers. Even though the multipliers should be positive when a negative fiscal shock leads to a negative reaction of a variable, we plot them with a negative sign to keep in mind that the output gap and inflation actually react negatively in response to the fiscal spending cut. In each figure, the upper-right chart illustrates the interest rate's path for each simulation while the lower-right chart shows the relative multipliers, i.e. the ratios between the multipliers obtained under constrained monetary policy and when monetary policy is active. For the instantaneous multipliers the ratio refers to the peak while in the case of the cumulative multipliers it corresponds to the limiting value as $t \to \infty$.

i. Scenarios with exogenously-imposed interest rate constraints

Figures 1 and 2 plot the results of the scenarios where monetary policy has been restricted exogenously for a period from one up to twelve quarters and agents fully anticipate this constraint. In response to a one percent of GDP fiscal spending cut the instantaneous output multiplier in QUEST III reaches its peak on impact and ranges between 0.84 and 1.84, depending on the length of the binding constraint. Such a result is not surprising in a New Keynesian model given that the forward-looking agents fully anticipate the length of constrained monetary policy and adjust their consumption and investment decisions immediately following the shock. The fact that the instantaneous multiplier on inflation does not show a significant difference on impact is simply a result of our choice to look at the annual

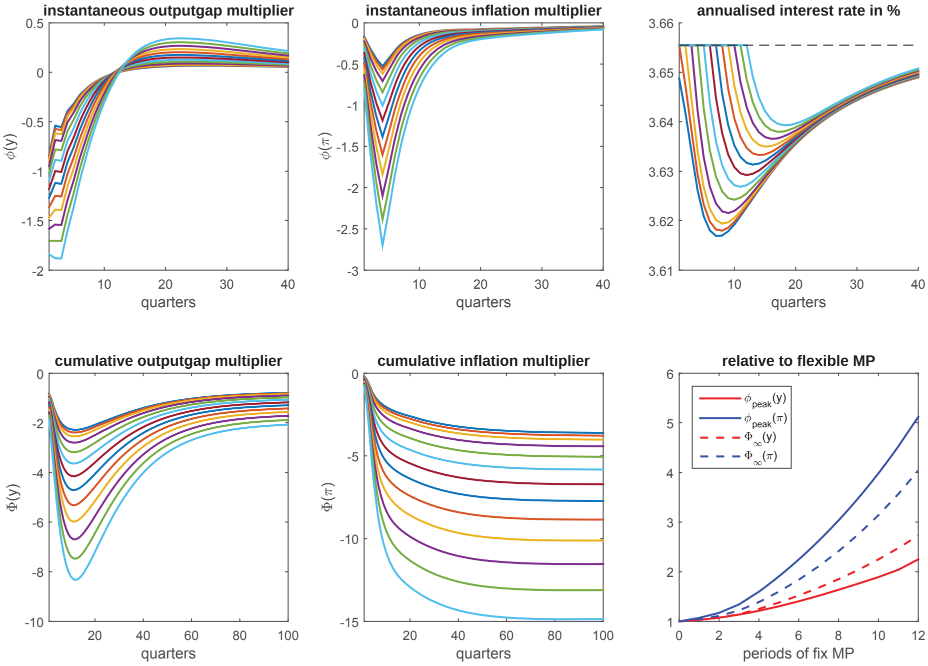

Figure 1: Instantaneous and cumulative fiscal multipliers on the output gap and inflation when monetary policy is *anticipated to be exogenously constrained* up to twelve quarters in *QUEST III*. The lower right panel shows the peak of the instantaneous and the limit of the cumulative multipliers relative to the flexible monetary policy case for each simulation.

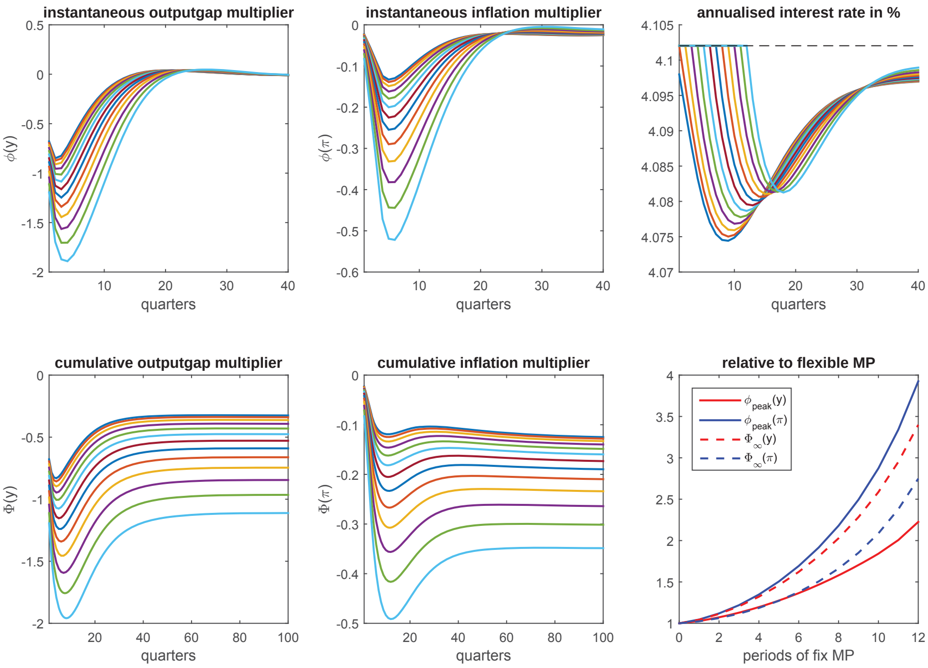

Figure 2: Instantaneous and cumulative fiscal multipliers on the output gap and inflation when monetary policy is *anticipated to be exogenously constrained* up to twelve quarters in *SW03*. The lower right panel shows the peak of the instantaneous and the limit of the cumulative multipliers relative to the flexible monetary policy case for each simulation.

inflation.[3] For the same reason inflation peaks in period four. However, the dispersion of the inflation multiplier at its peak is huge ranging from 0.53 to 2.70. It is way higher than the dispersion of the output multiplier. Moreover, Figure 1 illustrates a clear over-proportional relationship between the length of monetary policy constraint and the size of the inflation multiplier. As a consequence, in the case of a longer constrained monetary policy, the gap between the inflation and output multipliers becomes not only reduced but even reversed.

In the case of SW03, the overall picture is quite similar with the main difference that the model features some stronger endogenous inertia (related to a degree of price stickiness which in SW03 is largely determined by the Calvo scheme while in QUEST III stems from convex adjustment costs implying a more flexible price setting framework). The instantaneous output multiplier in SW03 reaches its peak between periods two and four and ranges from 0.85 to 1.89. The inflation multiplier also peaks somewhat later with values between 0.13 and 0.52. Compared to QUEST III, the SW03 instantaneous multipliers on output are strikingly similar in the peak. At the same time, the SW03 inflation multiplier is much smaller in absolute value. In SW03 we therefore do not observe the phenomenon of a closing gap between the inflation and output multipliers. Nonetheless, the length of the interest rate constraint exhibits a strong non-linear impact on inflation also in SW03. Finally, the higher degree of endogenous inertia in SW03 as compared to QUEST III directly translates into differences in the medium to long-run effects. Whereas the QUEST III output gap bounces back pretty strongly (the response turns positive after roughly three years and even 'overshoots' considerably), the SW03 response is less dynamic. This also explains why the QUEST III interest rate is never reduced below the values observed in simulations that assume shorter period of monetary policy constraint. With a more dynamic response in the output gap and inflation there is no need for monetary policy to provide stronger stimulus once it turns active again. In the less dynamic SW03 model the interest rate exhibits some twist implying that the longer the interest rate is held constant, the longer will it be kept on a lower level afterwards.

Turning now to the cumulative multipliers, the two models reveal one common and one contradicting result. The common result is the over-proportional increase of both output and inflation multipliers when the interest rate is held fixed for a longer period. Yet, whereas

[3] In a linearised quarterly model the annual inflation in period t is the sum of the per period (quarter-on-quarter) inflation rates from period $t-3$ until t. The initial response is therefore muted as the previous three quarter-on-quarter inflation rates are still in the steady state. The choice to look at the annual inflation rate is obviously somewhat arbitrary. It should be noted, though, that the qualitative results are not influenced by that. Moreover, using the annual inflation rate is a more conservative option as the moving sum smooths out hikes in the quarterly inflation.

the cumulative multiplier on inflation in QUEST III is in general above the one on output, this cannot be observed in SW03. This result is not surprising given that in SW03 the instantaneous inflation multiplier is always below the instantaneous output multiplier. The reason why the cumulative multipliers in SW03 are overall much smaller than in QUEST III is the persistence of the fiscal shock. As explained by equation (6), everything else equal, a higher persistence in government spending reduces the cumulative multiplier. The very similar instantaneous output multipliers in the two models are in fact a result of two different fiscal spending cut plans. Although we apply an initial spending cut of the same size to both models, the much higher persistence of the shock process in SW03 ($\rho = 0.94$) compared to QUEST III ($\rho = 0.3$) results in a much higher overall spending reduction. Consequently, the cumulative multiplier is smaller.

Figures 3 and 4 plot the results for the same type of interest rate constraint as discussed above but with different assumption about the agent's expectation. In these simulations, the constrained monetary policy is unanticipated and agents are continuously surprised about the length of the binding constraint. In fact, the figures clearly show that the instantaneous output multiplier in both models is hardly influenced by the length of the binding constraint. This is again not surprising given that the forward-looking agents base their decisions on their expectations about the future. Since monetary policy is not anticipated to stay fixed, the agents behave each period as if the interest rate were to follow the usual Taylor rule from the next period onwards. Thus, the impact on the economy in the first period following the shock is the same regardless of the duration of the interest rate constraint. Consequently, the more dynamic a model is, the earlier do its multipliers reach the peak. In QUEST III the instantaneous multipliers on output and inflation reach their peaks in period one and four, respectively. In SW03, in turn, the instantaneous output multiplier reaches its peak only in period three and the instantaneous inflation multiplier levels off in period six. The somewhat delayed reaction reflects the fact that the SW03 model is less dynamic as compared to QUEST III.[4] In quantitative terms, in both models the peaks of the instantaneous fiscal multiplier on output obtained under "unanticipated" scenarios can be up to two times smaller as compared to the simulations where the length of the binding constraint was fully anticipated by the economic agents. Looking at the analogues differences in the peaks of instantaneous multipliers on inflation, they can be up to four times smaller in QUEST III and up to three times smaller in SW03, depending on the length of the binding constraint.

The comparison of the anticipated and the unanticipated instantaneous multipliers nicely

[4]For the reason why inflation peaks later than output see Footnote 3 on annual versus quarterly inflation.

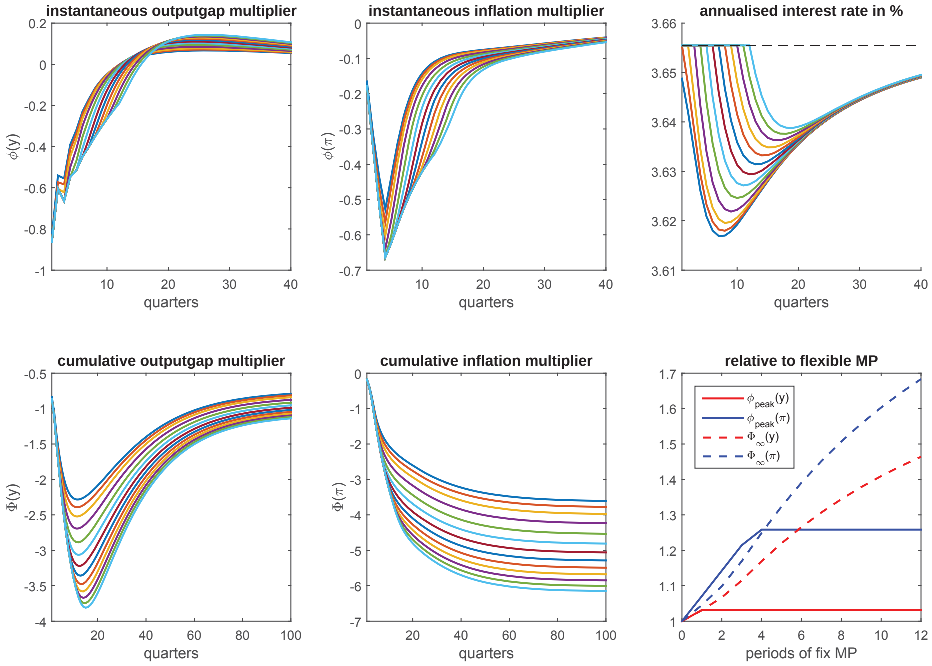

Figure 3: Instantaneous and cumulative fiscal multipliers on the output gap and inflation when monetary policy is *unanticipated to be exogenously constrained* up to twelve quarters in *QUEST III*. The lower right panel shows the peak of the instantaneous and the limit of the cumulative multipliers relative to the flexible monetary policy case for each simulation.

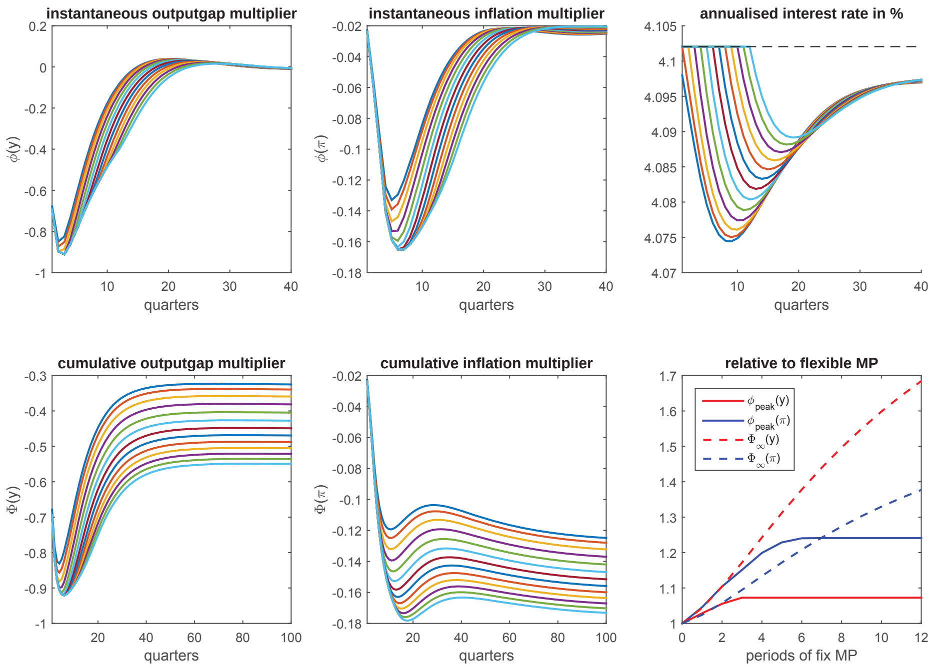

Figure 4: Instantaneous and cumulative fiscal multipliers on the output gap and inflation when monetary policy is *unanticipated to be exogenously constrained* up to twelve quarters in *SW03*. The lower right panel shows the peak of the instantaneous and the limit of the cumulative multipliers relative to the flexible monetary policy case for each simulation.

illustrates the importance of cumulative multipliers, as pointed out by Uhlig (2010). Indeed, the instantaneous fiscal multipliers observed in the scenarios with anticipated monetary policy correctly capture the length of constrained monetary policy. However, using the same multiplier to evaluate the impact of the duration of the interest rate constraint when monetary policy is unanticipated can lead to wrong conclusions. At this point the cumulative multiplier offers a better evaluation measure as it incorporates developments before and after the peak of the instantaneous multiplier. In fact, the cumulative multipliers in both cases – anticipated and unanticipated monetary policy – tend to show qualitatively similar results. They increase with the length of the period during which monetary policy is constrained.

ii. Scenarios with endogenously-driven interest rate constraints

We now turn to the analysis of scenarios where monetary policy is constrained by some lower bound. Three important differences relative to the "exogenous" scenarios need to be mentioned here. First, the length of the binding lower bound is now determined endogenously by the economic system. Second, whereas the first two scenarios, which mimic "forward guidance", could be applied symmetrically to either positive or negative fiscal shocks, the lower bound scenario yields different results for negative shocks that push the interest rate to its floor as compared to positive shocks that tend to shorten the period of the binding constraint. Third, in the exogenous "forward guidance" scenarios where the interest rate is fixed at the steady-state level, the constraint only holds as long as chosen by the modeller. After that, the interest rate is perfectly flexible again and is also heavily used to ease the monetary stance below the steady state. The endogenous lower bound is, in turn, present at all times and the interest rate can therefore never fall below that bound.

As explained in Section II, we look at two types of scenarios that employ the endogenously-driven interest rate constraint. We first impose the lower bound to be below, but close to, the steady state. Next, we relax this assumption and allow the interest rates to reach the zero level. The reason for such an approach is twofold. First, given our choice to set the size of the fiscal spending cut to one percent of GDP, the shock does not generate sufficient model dynamics to push the interest rate to the zero lower bound. Second, we want to illustrate the non-linearities stemming from the lower bound constraint, for which we focus on the distance between the initial level of the interest rate (i.e. prior to the fiscal shock) and the value where the constraint becomes binding. The results, discussed at more length below, illustrate that the smaller this distance (i.e. the room left for a central bank to manoeuvre), the larger the multipliers. Such a set-up, however, corresponds only to a thought experiment as it is obviously implausible that a central bank would face an endogenous bound below or at 3.6 (QUEST III) or 4.1 (SW03) percent. Therefore, in the final scenario we introduce a negative demand shock which pushes the economy close to the zero lower bound and then we look again at the spending cut responses. The size of the negative demand shock determines how 'strong' the zero lower bound is already binding when the fiscal shock occurs.

Figures 5 and 6 plot the results when monetary policy is endogenously facing different lower bounds that are set slightly below the steady-state value of the interest rate. The values for the lower bound are calibrated such that the lowest value does not pose a constraint for monetary policy in response to a one percent of GDP fiscal spending cut and such that subsequent values imply a constrained monetary policy ranging from one to twelve quarters. It is quite apparent that the multipliers overall look similar to the case of exogenously-fixed interest rates where monetary policy is anticipated. This is due to the fact that in the simulation with an endogenous interest rate constraint, we maintain the assumption of fully rational and forward-looking agents who understand the implications of the constraint for the model dynamics. Therefore, they always know where the lower bound is and for how long the interest rate constraint is going to be binding.

In both models, the peak of the instantaneous multipliers on output and inflation shows a strong over-proportional response the closer the lower bound gets to the steady state, with the reaction of inflation exhibiting the steeper curvature. In QUEST III the gap between the instantaneous multiplier on output and on inflation is again closed and in the extreme case reversed. Also as before, the cumulative multiplier on inflation is always above the one on output in QUEST III, and now even in SW03 the curvature of the relative cumulative multipliers is somewhat similar. In quantitative terms, the multipliers are smaller compared to the exogenously-imposed constraint where monetary policy is anticipated. This can, however, be easily explained by the fact that, unlike in the "exogenous" scenarios, here monetary policy is not constrained at the steady state but somewhat below it and can therefore immediately stimulate the economy through some interest rate reduction. Overall, this experiment illustrates that the less room the central bank has to manoeuvre, the larger the multipliers.

Finally, Figures 7 and 8 plot the results when monetary policy is endogenously facing the zero lower bound. Given that it would require an unrealistically high spending cut for the interest rate to reach the zero lower bound, we simulate the effects of a spending cut that is preceded by a negative demand shock of different sizes as in Erceg and Lindé (2011). The size of fiscal multipliers is then calculated as a difference between the variables in the "crisis only" scenario and the combined "crisis-spending cut" scenario. The interest rate shown in

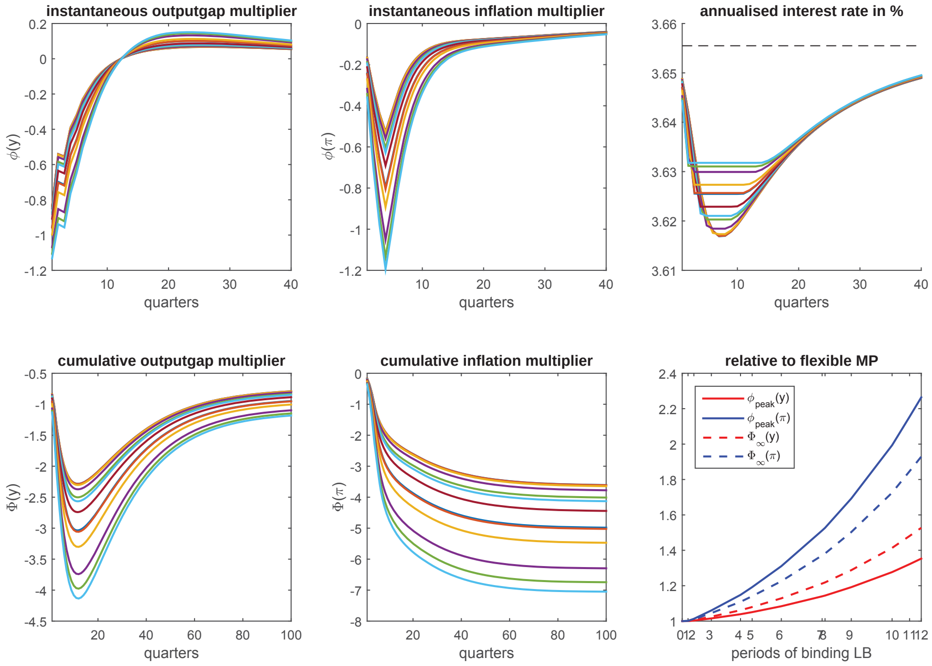

Figure 5: Instantaneous and cumulative fiscal multipliers of the output gap and inflation with an *endogenous lower bound* at various levels in *QUEST III*. The lower right panel shows the peak of the instantaneous and the limit of the cumulative multipliers relative to the flexible monetary policy case for each simulation. The x-axis is not linear because it is linearly arranged according to the levels of the constraint instead of the number of binding periods.

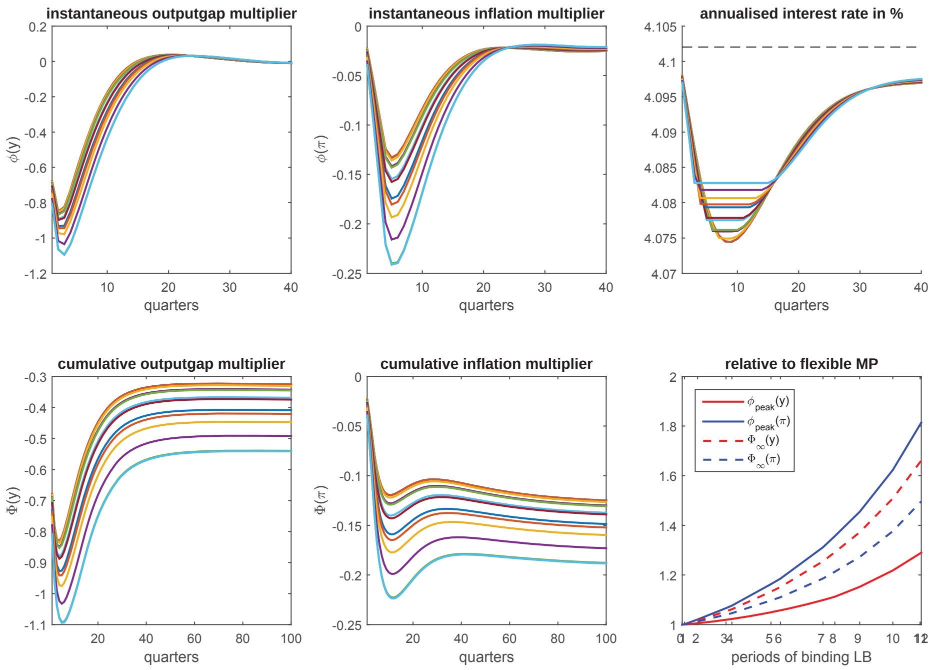

Figure 6: Instantaneous and cumulative fiscal multipliers of the output gap and inflation with an *endogenous lower bound* at various levels in *SW03*. The lower right panel shows the peak of the instantaneous and the limit of the cumulative multipliers relative to the flexible monetary policy case for each simulation. The x-axis is not linear because it is linearly arranged according to the levels of the constraint instead of the number of binding periods.

the figures is from the combined scenario. The size of each "crisis" shock is calibrated such that the mildest one does not lead to a constrained monetary policy and such that more severe "crisis" shocks lead to a constrained monetary policy ranging from one to twelve quarters. The sign of the fiscal shock is now getting very crucial as a spending cut keeps the economy even longer at the zero lower bound. On the contrary, a spending stimulus would not be accompanied by a constrained monetary policy. Thus, all the results presented here are only applicable to a spending cut.

Also in this scenario the overall results look somewhat similar to the case of exogenously-fixed interest rates where the monetary policy reaction is anticipated. Such an outcome can again be attributed to the fact that the forward-looking agents fully anticipate the zero lower bound and the binding period. In this scenario, however, the quantitative results are even stronger, i.e. the size of observed multipliers is larger. It is not due to the negative dynamics resulting from the demand crisis since that effect is netted out by means of differencing. It is rather stemming from the fact that monetary policy is already at the zero lower bound and can therefore neither provide a small response in the short-term (as in the endogenous case with varying lower bounds) nor ease monetary policy after the binding period is over (as in the case of exogenously-fixed anticipated monetary policy). In this respect, the fourth scenario comes closest to the idea of a plausibly constrained monetary policy at the zero lower bound.

Looking at Figures 7 and 8, the instantaneous multiplier on output goes above two in both models and the multiplier on inflation even reaches up to 3.5 in QUEST III. As in the previous scenarios, the inflation response in SW03 is somewhat muted. Nonetheless, both models exhibit a pronounced non-linear positive relationship between the length of the binding constraint and the size of relative multipliers. Recalling that the latter is the ratio between fiscal multipliers obtained between the scenarios where monetary policy is constrained and where it is allowed to float, the finding illustrates the degree to which the impact of a fiscal spending cut is affected by the presence of the ZLB. In particular, when the ZLB is binding for the longest time period (twelve quarters in our analysis), the relative instantaneous multiplier on inflation becomes as large as six in QUEST III and around four in SW03. The relative instantaneous multiplier on output rises up to two in both models. The relative cumulative multipliers, in turn, are of the magnitude of five (QUESTIII) and three (SW03) for inflation and four (QUESTIII) to three (SW03) for output.

To sum up, all multipliers in both models show an over-proportional reaction when monetary policy is anticipated to stay constant. This finding is not entirely new to the literature, in

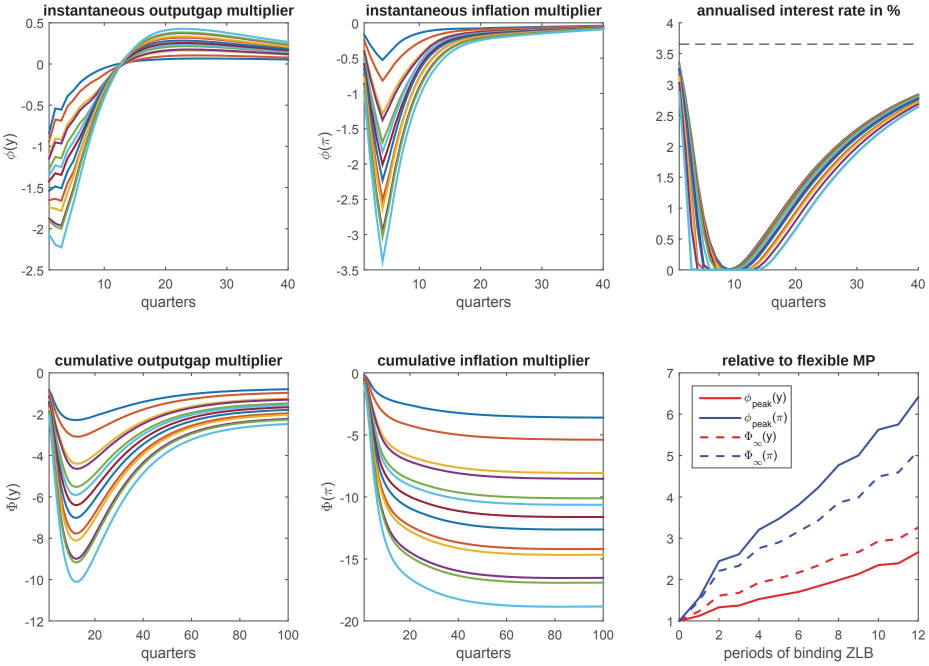

Figure 7: Instantaneous and cumulative fiscal multipliers of the output gap and inflation with an *endogenous zero lower bound* in *QUEST III*. The lower right panel shows the peak of the instantaneous and the limit of the cumulative multipliers relative to the flexible monetary policy case for each simulation.

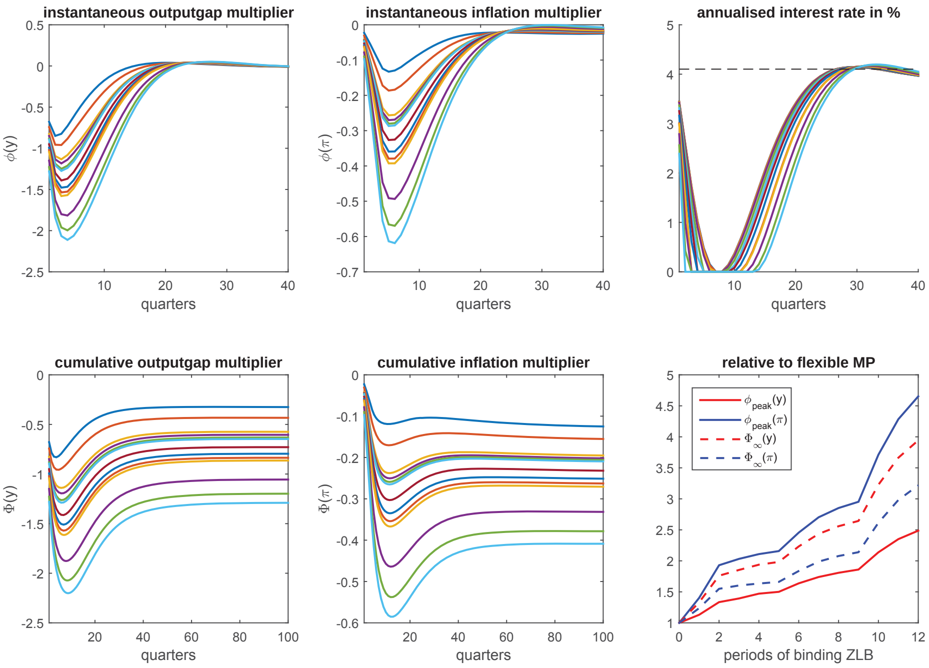

Figure 8: Instantaneous and cumulative fiscal multipliers of the output gap and inflation with an *endogenous zero lower bound* in *SW03*. The lower right panel shows the peak of the instantaneous and the limit of the cumulative multipliers relative to the flexible monetary policy case for each simulation.

particular for the fiscal multiplier on output (see Coenen et al., 2012; Burgert and Wieland, 2013; Schwarzmüller and Wolters, 2014). Our novel finding is that this over-proportionality is stronger for the multiplier on inflation than on output, and in some cases might even lead to a reversal of the initial gap between the output and inflation multipliers, as illustrated by the QUEST III model.

VI. Global Sensitivity Analysis (GSA)

In the final part of the paper, we want to understand where the difference ("gap") in the over-proportionality of the fiscal multipliers on output and on inflation, when monetary policy is constrained, comes from. For that purpose, we look at which parameters are the main drivers of that gap in the models we use. Given the numerous simulations we presented so far, we limit our analysis to selected settings which we perceive as particularly interesting. We only analyse settings with exogenously-imposed constraints and refer to them from now on as "fix" monetary policy for a specified period. The reason for that is our finding that the agents' expectations are overall more important for the fiscal multipliers than the modelling choice between exogenous and endogenous constraints. In addition, the exogenous settings allow us to study both anticipated and unanticipated monetary policy in a more meaningful way as compared to the endogenously-imposed constraints. In the endogenous set-up it would not be in line with our assumption of rational agents to assume that the endogenous constraint is not anticipated. Moreover, we are interested in both instantaneous and cumulative fiscal multipliers. As we have shown in the previous sections, the former is a measure that well captures the dynamics associated with anticipated monetary policy while the latter is more meaningful in the context of unanticipated monetary policy. Therefore, we focus on the following two "gaps" in this section. First, the gap between the peaks of the instantaneous fiscal multipliers on output and inflation when monetary policy is fully anticipated:

$$\phi_\Delta \equiv \phi_{peak}(\hat{y}) - \phi_{peak}(\hat{\pi}) = \frac{\hat{y}_{peak} - \hat{\pi}_{peak}}{\hat{g}_T \frac{\bar{G}}{\bar{Y}}} \tag{8}$$

Second, the gap between the limiting values of the cumulative multipliers on output and inflation when monetary policy is unanticipated:

$$\Phi_\Delta \equiv \Phi_\infty(\hat{y}) - \Phi_\infty(\hat{\pi}) = \frac{\sum_{s=0}^{\infty} \left(\frac{\phi_s(\Delta)^{\frac{1}{s}}}{\bar{R}} \right)^s}{\sum_{s=0}^{\infty} \left(\frac{\rho}{\bar{R}} \right)^s} \tag{9}$$

In order to conduct a sound analysis we utilise the Global Sensitivity Analysis (GSA) toolbox by Ratto (2008) which is now integrated into Dynare (see Adjemian et al., 2011). The general idea behind GSA is a decomposition of some result of interest into key sub-components by linking them to relevant input factors. In our set-up, the results of interest are the multiplier gaps defined in equations (8) and (9), and the input factors are the parameters of the models that determine the size of underlying multipliers. The global part of the analysis is the technique by which the single impact of one input factor on the overall result is obtained. Instead of stepwise changing one factor after another to see how the result changes, GSA changes all factors at the same time for a large number of repetitions in a Monte Carlo (MC) simulation and then singles out each factor's impact by means of a state dependent regression.[5] To understand the formal approach, we follow the description of Ratto (2008).[6] Each of the multiplier gaps M is a function of the model parameters with a general form $M = f(x_1, ..., x_k)$ where each $x_i \in \{1, 2, ..., k\}$ denotes one of the k parameters. Since $f(.)$ is unknown for the complicated question at hand and can take any analytical form (if it exists at all), one can use a High Dimensional Model Representation (HDMR, see Sobol, 1993) which takes care of possible non-linearities. HDMR decomposes $f(.)$ into a finite number of terms with increasing dimensionality:

$$M = f(x_1, ..., x_k) = f_0 + \sum_i f_i + \sum_i \sum_{j>i} f_{ij} + ... + f_{12...k} \tag{10}$$

Each term is a function of parameters which appear in the own index only and equals

$$\begin{aligned} f_0 &= \mathbb{E}(M) \\ f_i = f(x_i) &= \mathbb{E}(M|x_i) - f_0 \\ f_{ij} = f(x_i, x_j) &= \mathbb{E}(M|x_i, x_j) - f_i - f_j - f_0 \end{aligned} \tag{11}$$

and so on.[7] The f_i terms are the ones we are after and are called main effects. For each parameter x_i the corresponding main effect f_i tells us to what degree and in which direction the result M moves around its overall mean given that we only know x_i. The higher-order terms with more than one index represent the joint interaction effect of certain parameter groups which we are not interested in at this point. In order to judge the importance of each

[5] As pointed out by Ratto (2008), this approach helps to obtain an impact for each factor which is independent of the other factors. In a stepwise approach, each factor's impact crucially hinges on where one fixes the other factors.

[6] We only present the main idea of GSA such that the reader knows what the later results tell us. For a technical description, validation and derivation see Ratto (2008).

[7] $\mathbb{E}(M|x)$ is the mathematical expectation of M conditional on the information set x.

factor's main effect we define sensitivity indices as $S_i \equiv \frac{V(f_i)}{V(M)}$ with $V(f_i)$ being the partial variance of each parameter's main effect f_i and $V(M)$ being the total unconditional variance of M. The higher the sensitivity index, the more important is the variation of a parameter in explaining the variation in the respective multiplier gap. Finally, given the inputs and resulting outputs from a MC simulation we use the State Dependent Regression (SDR) of the GSA toolbox to obtain the main effects (see Ratto et al., 2007). The non-parametric functions $f(x_i)$ are first smoothed and then shown in a polynomial representation.

Before turning to the the results of the GSA, we need to define the parameter space from which we draw the parameters in the MC simulation. In order to get a meaningful decomposition in equation (10) it is crucial to draw each parameter independently. As a result, the decomposition is unique and features orthogonal factors. In choosing the parameter space it becomes apparent why we use the QUEST III and SW03 models. They are not only widely used but also estimated and therefore report distributions including their moments after estimation. Using these estimated distributions seems to be the most natural choice for drawing random parameter samples.[8] Tables 1 and 2 list the parameters of QUEST III and SW03 including the type of distribution, its mean, standard deviation and support. The latter is only important for the beta distributions which are partially stated in generalised form. Whereas the standardised beta distribution has only a support from zero to one, the generalised distribution can have any finite support as it is simply a linear transformation of the standardised values. It is important to note that both models are estimated with Bayesian techniques and that the stated distributions apply, strictly speaking, only to the prior of each parameter. At this point we take a simplifying assumption in that we assume that the posteriors follow the same distributions. For a more elaborate discussion on the specifications of the parameters the original papers by Ratto et al. (2009) and Smets and Wouters (2003) should be consulted.

Table 3 shows the three parameters and their distributions for the interest rate rule which we use in both models instead of the model-specific rules. The coefficients on inflation and the output gap are taken from the original Taylor rule by Taylor (1993). Since the parameters differ not too much from the model-specific estimates we use an average of the estimated standard deviations. In the same way we obtain a mean and standard deviation for the smoothing coefficient. Finally, we follow Ratto et al. (2009) in terms of distribution types who assume beta distributions for all three parameters. In contrast, Smets and Wouters

[8]Both models feature calibrated parameters, too. Those will not be part of the GSA because there exists no information about their potential variation.

Table 1: Parameters of QUEST III

Name	Description	Distrib.	Mean	Std. Dev.	Support	
σ^C	inverse of intertemp. elasticity of substitution	Gamma	4.0962	0.8130	0.00	$+\infty$
slc	share of liquidity constrained households	Beta	0.3507	0.0754	0.00	1.00
h^C	habit persistence in consumption	Beta	0.5634	0.0412	0.00	1.00
h^L	habit persistence in labour	Beta	0.8089	0.0778	0.00	1.00
κ	inverse of Frisch elasticity of labour supply	Gamma	1.9224	0.4438	0.00	$+\infty$
risk	external financial intermediation premium	Beta	0.0200	0.0074	0.00	0.04
rp	equity risk premium	Beta	0.0245	0.0026	0.00	0.04
$\gamma_{ucap,2}$	capital utilisation adjustment costs	Beta	0.0453	0.0128	0.00	0.10
ω^X	share of domestic consumption and investment	Beta	0.8588	0.0196	0.60	1.00
σ^X	elast. of subst. for exported and foreign goods	Gamma	2.5358	0.3200	0.00	$+\infty$
σ^M	elast. of subst. for domestic and imported goods	Gamma	1.1724	0.2136	0.00	$+\infty$
τ^{CG}_{Lag}	smoothing in fiscal consumption rule	Beta	-0.4227	0.1041	-1.00	1.00
τ^{CG}_{Adj}	target deviation response in consumption rule	Beta	-0.1567	0.0442	-1.00	0.00
τ^{CG}_0	output gap response in consumption rule	Beta	-0.0754	0.1066	-1.50	1.50
τ^{IG}_{Lag}	smoothing in fiscal investment rule	Beta	0.4475	0.0895	0.00	1.00
τ^{IG}_{Adj}	target deviation response in investment rule	Beta	-0.1222	0.0461	-1.00	0.00
τ^{IG}_0	output gap response in investment rule	Beta	0.1497	0.0996	-1.50	1.50
b^U	coefficient on labour gap in fiscal transfer rule	Beta	0.9183	0.0949	-1.50	1.50
γ_K	investment-capital adjustment costs	Gamma	76.0366	20.5526	0.00	$+\infty$
γ_I	investment adjustment costs	Gamma	1.1216	0.5185	0.00	$+\infty$
γ_L	labour adjustment costs	Gamma	58.2083	12.2636	0.00	$+\infty$
γ_P	price adjustment costs	Gamma	61.4414	10.4208	0.00	$+\infty$
γ_{PM}	import price adjustment costs	Gamma	1.6782	0.9092	0.00	$+\infty$
γ_{PX}	export price adjustment costs	Gamma	26.1294	16.8398	0.00	$+\infty$
γ_W	wage adjustment costs	Gamma	1.2919	0.8261	0.00	$+\infty$
γ_{WR}	sluggishness in real wage adjustments	Beta	0.2653	0.1315	0.00	1.00
sfp	producer share with forward-looking pricing	Beta	0.8714	0.0567	0.00	1.00
sfpm	importer share with forward-looking pricing	Beta	0.7361	0.1227	0.00	1.00
sfpx	exporter share with forward-looking pricing	Beta	0.9180	0.0473	0.00	1.00
sfw	worker share with forward-looking wage setting	Beta	0.7736	0.1565	0.00	1.00
ρ^C	autocorrelation of demand shock	Beta	0.9144	0.0295	0.00	1.00
ρ^{CG}	autocorrelation of fiscal consumption shock	Beta	0.2983	0.1000	0.00	1.00
σ^{CG}	standard deviation of fiscal consumption shock	Gamma	0.0048	0.000346	0.00	$+\infty$

Note: We thank Marco Ratto for providing us with the supports for the generalised beta distributions.

(2003) assume a normal distribution for the coefficients on inflation and the output gap. Using the beta distribution allows us to restrict the support for the inflation reaction from 1.0 to 3.0 and the support for the output gap reaction from 0.0 to 1.5, which is important

Table 2: Parameters of SW03

Name	Description	Distrib.	Mean	Std. Dev.	Support	
φ	Investment adjustment costs	Normal	6.7711	0.022	$-\infty$	$+\infty$
σ_c	inverse of intertemp. elasticity of substitution	Normal	1.3533	1.026	$-\infty$	$+\infty$
h	habit persistence in consumption	Beta	0.5732	0.076	0.00	1.00
σ_l	inverse of Frisch elasticity of labour supply	Normal	2.3995	0.589	$-\infty$	$+\infty$
ϕ	Producer fixed costs	Normal	1.4077	0.166	$-\infty$	$+\infty$
ξ_e	Calvo employment stickiness	Beta	0.5990	0.050	0.00	1.00
ψ	capital utilisation adjustment costs	Normal	0.1690	0.075	$-\infty$	$+\infty$
ξ_w	Calvo wage stickiness	Beta	0.7367	0.049	0.00	1.00
ξ_p	Calvo price stickiness	Beta	0.9082	0.011	0.00	1.00
γ_w	share of wage indexation	Beta	0.7627	0.188	0.00	1.00
γ_p	share of price indexation	Beta	0.4694	0.103	0.00	1.00
ρ_b	autocorrelation of preference shock	Beta	0.8545	0.035	0.00	1.00
ρ_g	autocorrelation of fiscal spending shock	Beta	0.9493	0.029	0.00	1.00
g_y	standard deviation of fiscal spending shock	Inv gamma	0.3247	0.026	0.00	$+\infty$

Table 3: Parameters of the Taylor rule

Name	Description	Distrib.	Mean	Std. Dev.	Support	
ρ_i	smoothing in Taylor rule	Beta	0.9000	0.0150	0.00	1.00
ϕ_π	inflation coefficient in Taylor rule	Beta	1.5000	0.1500	1.00	3.00
ϕ_y	output gap coefficient in Taylor rule	Beta	0.5000	0.0500	0.00	1.50

in the MC simulation for not running too often into indeterminacy regions. In other words, the Taylor principle $\phi_\pi > 1$ is always satisfied.

In the MC simulation we draw 2,048 random and independent samples from the above specified parameter spaces. For each of the draws the differences of the instantaneous and cumulative multipliers on the output gap and inflation are calculated, as defined in equations (8) and (9). As an illustrating example, Figures 9 and 10 show the multipliers for an anticipated and unanticipated fix monetary policy in QUEST III for selected fixed policy periods.[9] The fluctuations of the multipliers with anticipated fix monetary policy, especially the instantaneous ones, are much larger for the reason discussed in Section V. The perfectly anticipated policy, as in Figure 9, in a model with forward-looking agents leads to a fully

[9]Figures showing the same MC simulation for SW03 can be obtained from the authors on request.

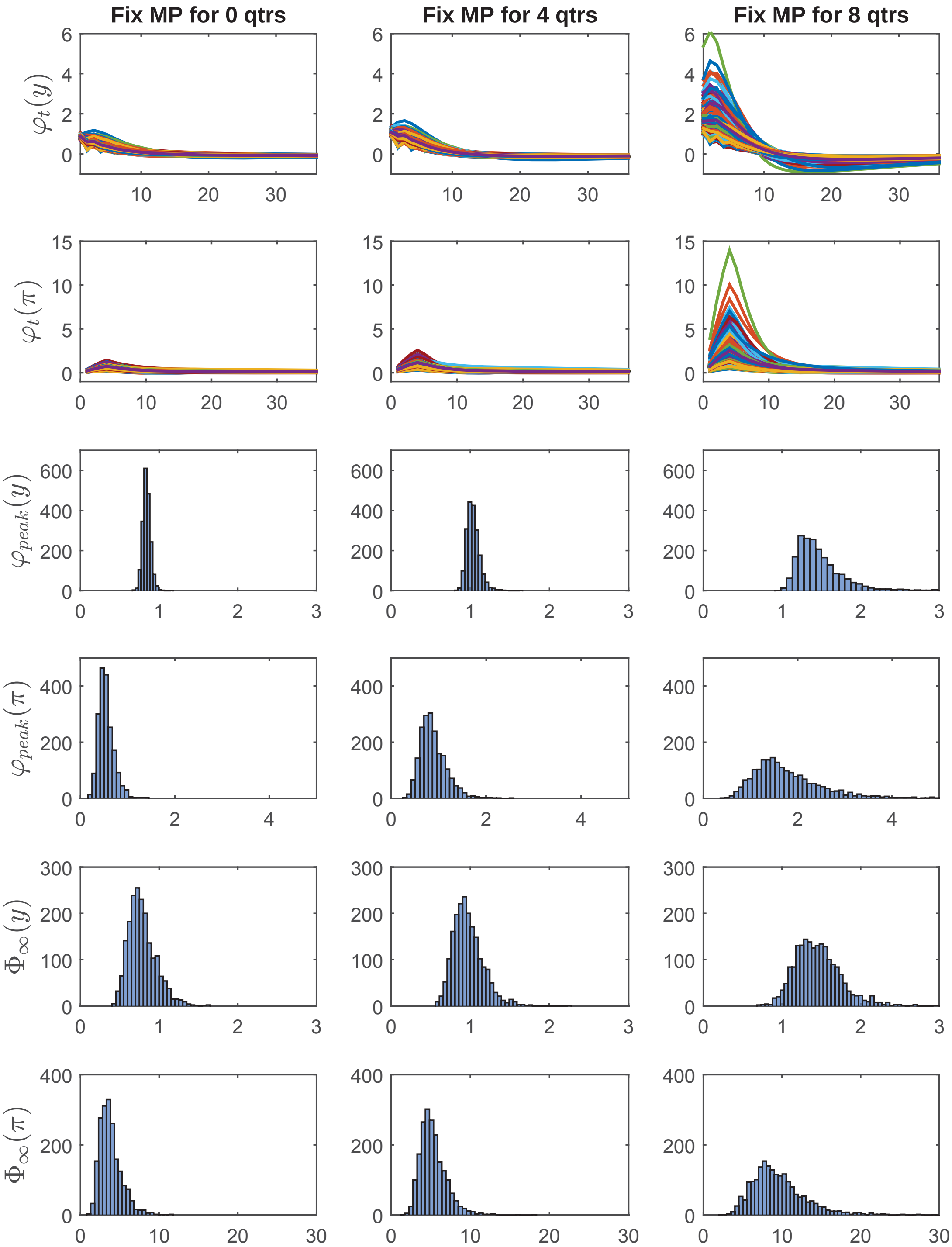

Figure 9: Instantaneous (complete paths and histogram of peaks) and cumulative fiscal multipliers (histogram of limits) of the output gap and inflation in *QUEST III* with flexible and *anticipated* fix monetary policy for 4 and 8 quarters. MC simulation with 2,048 repetitions.

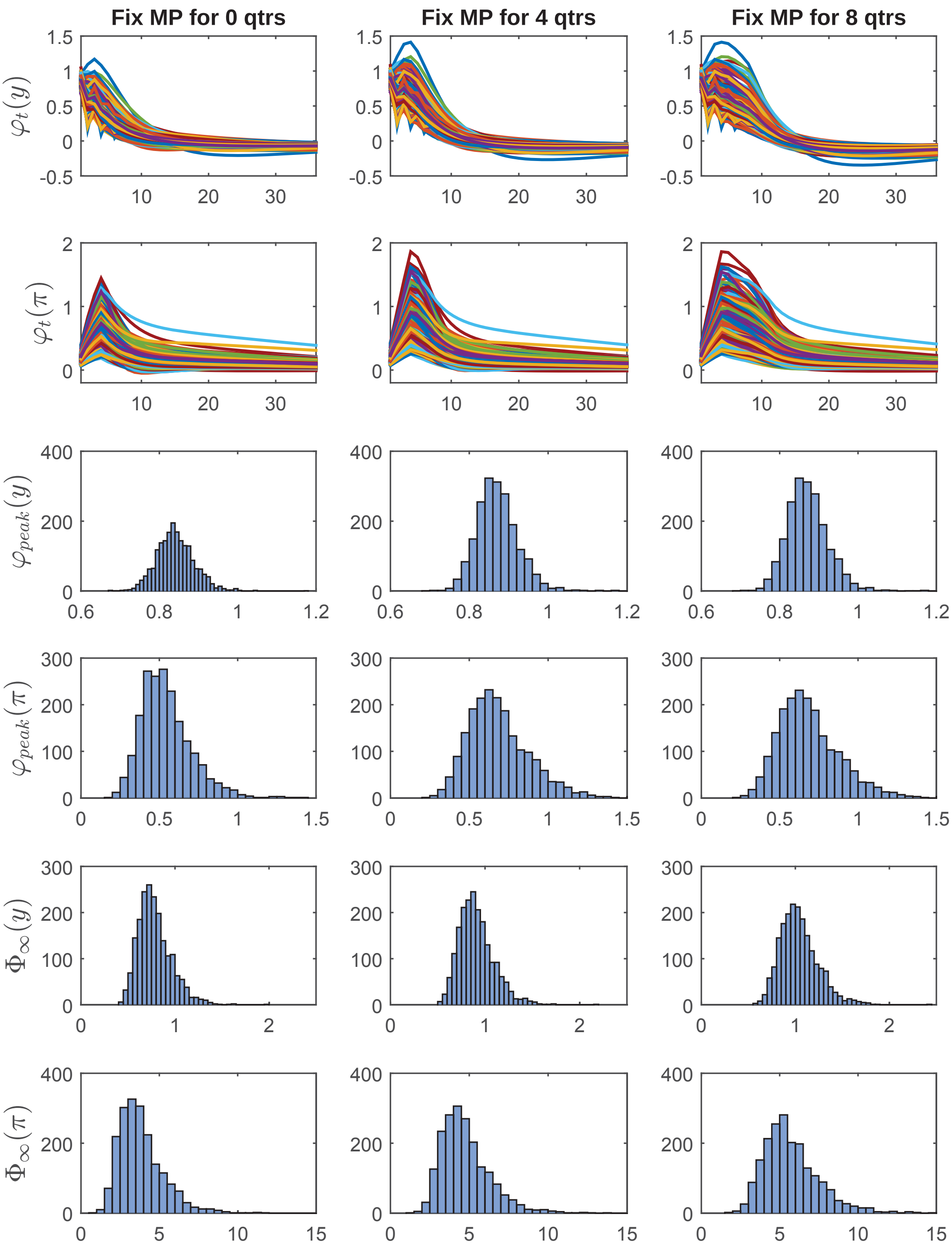

Figure 10: Instantaneous (complete paths and histogram of peaks) and cumulative fiscal multipliers (histogram of limits) of the output gap and inflation in *QUEST III* with flexible and *unanticipated* fix monetary policy for 4 and 8 quarters. MC simulation with 2,048 repetitions.

front-loaded reaction on impact. Hence, certain parameter constellations together with a longer fix monetary policy lead to very strong multipliers. With unanticipated fix monetary policy, as in Figure 10, the larger dispersion becomes more apparent in the cumulative multipliers as the fiscal and monetary policy combination has a relatively long-lasting effect. The problem of indeterminacy or instability ranges in both models from around two up to five percent of the drawings in the anticipated and unanticipated case. Avoiding indeterminate parameter drawings overall is hardly manageable as it would require to put more structure on the parameter space. Yet, ruling out certain parameter combinations a priori violates the assumption independent parameters.

Turning to the GSA results, Figures 11 to 14 show the results from the SDR for the selected simulations in both models, QUEST III and SW03. The analysis focuses in both models on fix monetary policy for eight quarters which we perceive as a reasonable time period. Each of the figures has 16 sub-plots showing the most important parameters in terms of the sensitivity index, the corresponding main effects (solid lines) and the 99.9 percent confidence bands (dotted lines). Those values where a parameter's main effect is outside the confidence interval have a statistically significant impact on the result's deviation from its unconditional expected value. The SDR provides a measure of fit (R^2) which shows how much of the respective multiplier gap can be explained by the overall variation of the parameters. The R^2 for anticipated fix monetary policy is smaller than the one for the unanticipated case in both models. This implies that the higher-order interaction terms of the parameters (which are part of the error term) are more important either because monetary policy is anticipated or because we look at the instantaneous instead of the cumulative multipliers. Moreover, the R^2 in QUEST III is higher no matter at which scenario we look at. There are two related reasons for that. First, the QUEST III model has a deeper model structure.[10] Thus, each parameter only has to capture a smaller channel in the model. Second, the estimated posterior standard deviations are overall smaller in QUEST III compared to SW03. This allows to pin down the effect of each parameter on the multiplier gaps more accurately.

For QUEST III, Figure 11 presents the results when monetary policy is anticipated to stay constant for eight quarters. The three most important parameters for the gap in the instantaneous multipliers on output and inflation are those governing nominal and real adjustment frictions. The higher the price adjustment costs (γ_P) and the producer share of forward-

[10]In QUEST III we analyse 33 estimated parameters, whereas in SW03 we analyse 14. More specifically, QUEST III has more frictions (real and nominal) and even disentangles similar frictions into smaller sub-frictions. In addition, there is an international or open-economy component as well.

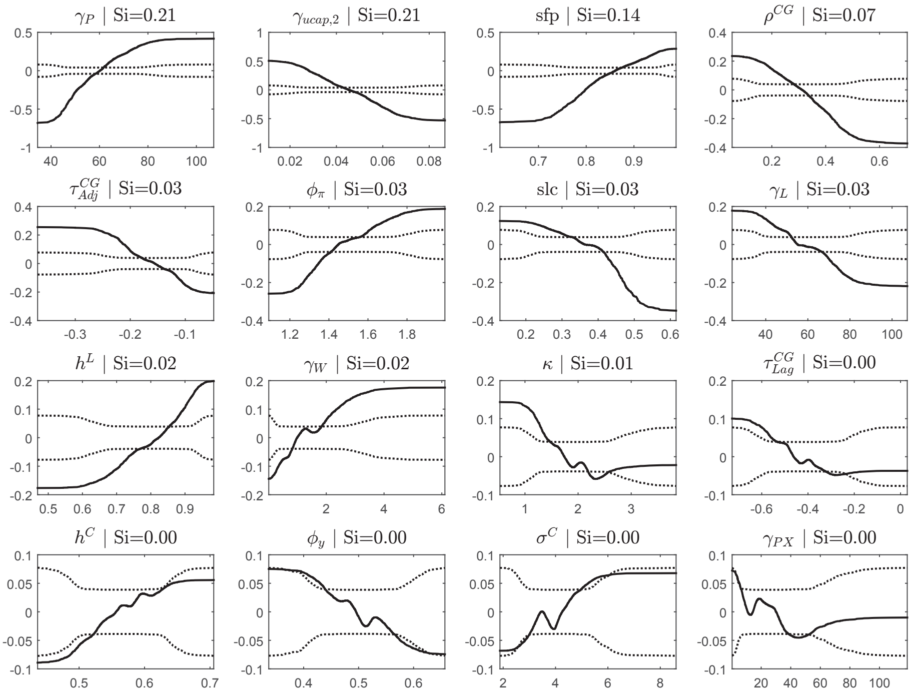

Figure 11: GSA based on 2,048 simulations with fix *anticipated* monetary policy for 8 quarters in *QUEST III*. The analysed result is the gap between the peaks in the *instantaneous* multipliers on the output gap and inflation. The SDR has an $R^2 = 0.84$. The figure contains subplots for the 16 parameters with the highest sensitivity index (Si), each showing the main effect (solid line) and the 99.9% ($\pm 3.09\sigma$) confidence bands (dotted lines).

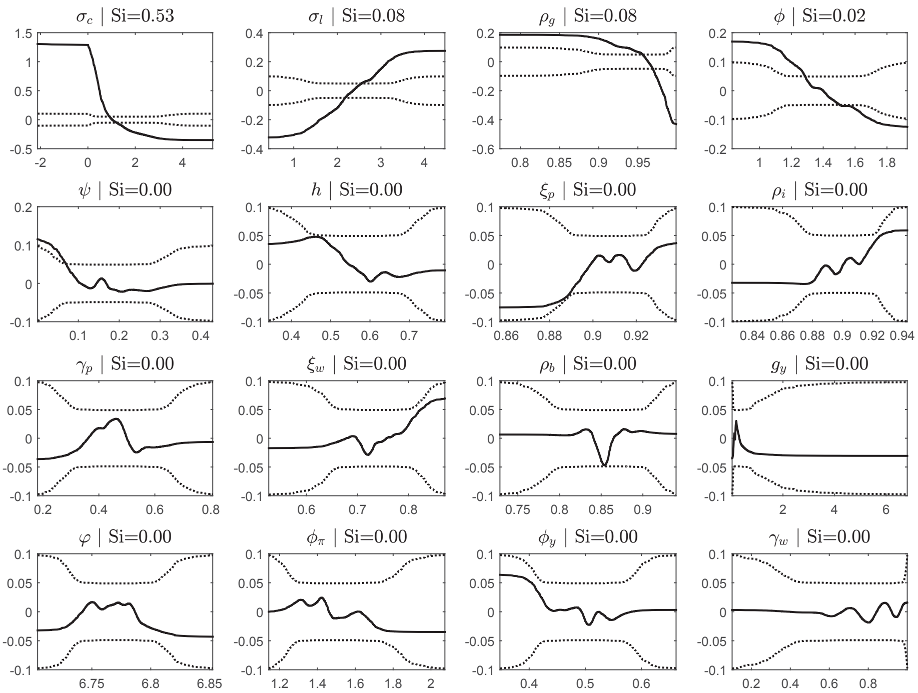

Figure 12: GSA based on 2,048 simulations with fix *anticipated* monetary policy for 8 quarters in *SW03*. The analysed result is the gap between the peaks in the *instantaneous* multipliers on the output gap and inflation. The SDR has an $R^2 = 0.75$. The figure contains subplots for the 16 parameters with the highest sensitivity index (Si), each showing the main effect (solid line) and the 99.9% ($\pm 3.09\sigma$) confidence bands (dotted lines).

looking pricing ('sfp'), the larger is the instantaneous multiplier on output than on inflation. The higher price adjustment costs reduce the willingness of the agents to change prices drastically. This is the more important the more forward-looking the agents are and therefore inflation peaks less in response to the fiscal spending cut. Higher capital adjustment costs ($\gamma_{ucap,2}$) lead to a dampening response of output which explains the parameter's negative relationship with the instantaneous multiplier gap ϕ_Δ. Fiscal and monetary policy parameters have a lower but nonetheless crucial impact. The spending cut itself matters only in terms of its persistence (ρ^{CG}) yet not in terms of its size. Similarly, the coefficient on the deviation from the spending target level in the fiscal consumption rule (τ^{CG}_{Adj}) exhibits a significant and negative relation with ϕ_Δ. Since τ^{CG}_{Adj} is negative this implies that if the fiscal shock is overall more persistent, either due to the higher persistence of the shock or because the fiscal consumption rule adjusts less in response to target deviations, the stronger is the multiplier on inflation relative to output. The most important parameter in the Taylor rule is the coefficient on inflation (ϕ_π). The higher it is, the stronger does the central bank stabilise inflation and thus the stronger the variation in output. Interestingly, the coefficient on output (ϕ_y) seems less important. This finding is consistent with Bi et al. (2013). In overall terms, frictions related to the real production side reduce the relative response of output, and frictions on the nominal production side reduce the relative response of inflation.

The analysis for the same scenario in SW03 is less straightforward, as shown in Figure 12. The results that remain similar are that the more rigid the real production sector (lower inverse of Frisch elasticity of labour supply σ_l or higher fixed costs φ) and the higher the persistence of the spending cut (ρ_g), the stronger is the multiplier on inflation than on output. Yet, nominal frictions such as the Calvo parameter for prices (ξ_p) and wages (ξ_w) or the shares of price and wage indexation (γ_p and γ_w) have no significant impact. Contrary to QUEST III, in SW03 the intertemporal elasticity of substitution (inverse of σ_c) has a very strong and positive impact. The variation in σ_c alone explains more than 50 percent of the variation on ϕ_Δ. When the intertemporal elasticity of substitution is low (high σ_c), households are less willing to accept large fluctuations in their consumption which translates into muted responses in output relative to inflation.[11] Interestingly, the Taylor rule coefficients do not play an important role in SW03.

Figures 13 and 14 present the results for the cumulative multiplier gaps Φ_Δ with unan-

[11] The parameter σ_c also measures the relative risk aversion of households. Thus, a similar intuition is that a higher risk aversion leads to less fluctuation in output than in inflation since households have a stronger will to smooth consumption.

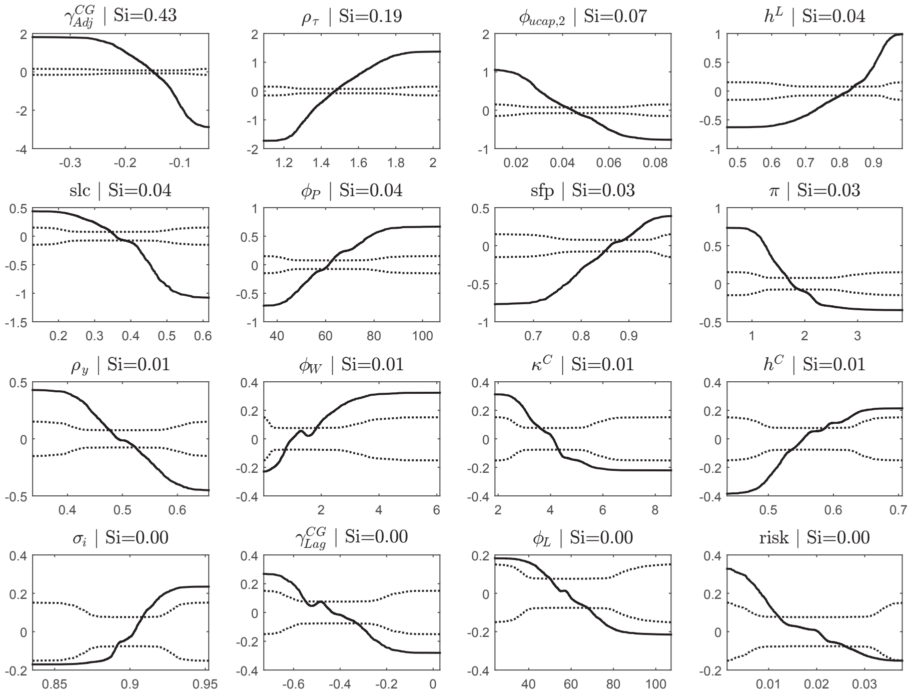

Figure 13: GSA based on 2,048 simulations with fix *unanticipated* monetary policy for 8 quarters in *QUEST III*. The analysed result is the gap between the limits of the *cumulative* multipliers on the output gap and inflation. The SDR has an $R^2 = 0.93$. The figure contains subplots for the 16 parameters with the highest sensitivity index (Si), each showing the main effect (solid line) and the 99.9% ($\pm 3.09\sigma$) confidence bands (dotted lines).

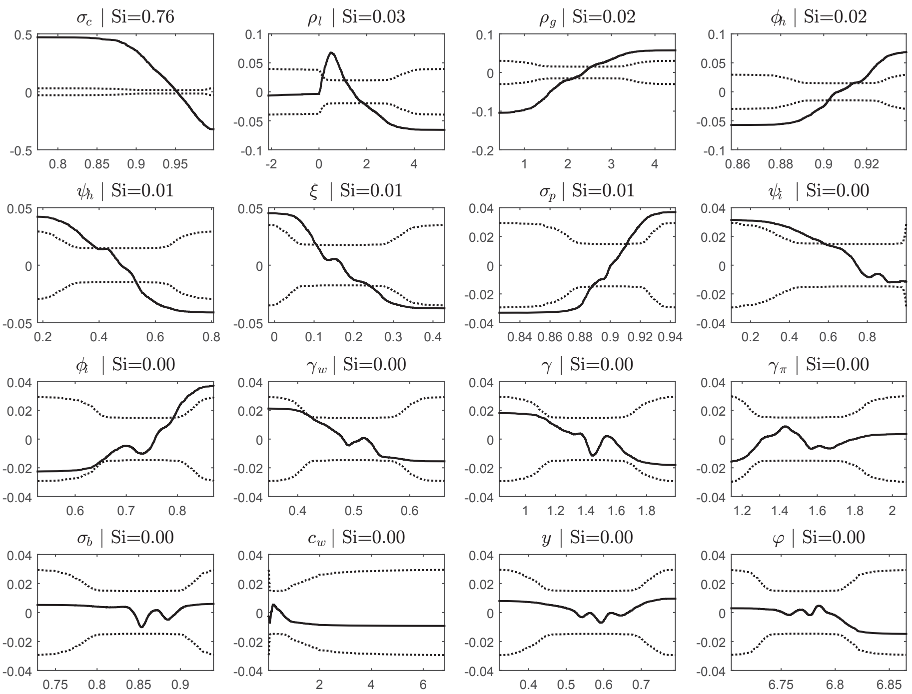

Figure 14: GSA based on 2,048 simulations with fix *unanticipated* monetary policy for 8 quartersin *SW03*. The analysed result is the gap between the limits of the *cumulative* multipliers on the output gap and inflation. The SDR has an $R^2 = 0.88$. The figure contains subplots for the 16 parameters with the highest sensitivity index (Si), each showing the main effect (solid line) and the 99.9% ($\pm 3.09\sigma$) confidence bands (dotted lines).

ticipated fix monetary policy for eight quarters. In QUEST III, shown in Figure 13, the most important parameters are almost the same as for the instantaneous multiplier gap with anticipated fix monetary policy, yet their ordering is different. Especially the coefficient on target deviations in the fiscal consumption rule (τ^{CG}_{Adj}) has now a sensitivity index of 0.43 and shows quite large main effects. The less fiscal consumption returns to its long-run target, the stronger is the impact on inflation than on output. The impacts of nominal and real frictions are qualitatively the same, just their magnitude is larger. This is due to the fact that we now consider the cumulative multiplier and not the instantaneous one. The Taylor rule coefficient on inflation (ϕ_π) is considerably more important and even the coefficient on the output gap (ϕ_y) has a significant impact, showing an intuitive negative relationship. Interestingly, the smoothing parameter in the Taylor rule (ρ_i) plays no role in any specification. Likewise, the parameter governing the persistence of the fiscal spending cut (ρ^{CG}) does not show up among the most important parameters contributing to the cumulative multiplier gap when fix monetary policy is unanticipated. This can be explained by the importance of τ^{CG}_{Adj} which already captures the persistence of the fiscal spending path to a large degree. As in the case of anticipated fix monetary policy, real frictions lead to a smaller and nominal frictions to a larger relative response of the cumulative multiplier on output than on inflation.

Finally, looking at the results for SW03, shown in Figure 14, the persistence of the spending shock (ρ_g) plays a huge role for the size of the cumulative multiplier. This is in line with its definition as in equation (6). The sign of the main effect is the same as for the instantaneous multiplier (a higher persistence means a stronger relative impact on inflation), yet its sensitivity index rises to as much as 0.76. The intertemporal elasticity of substitution (inverse of σ_C) still shows the positive relationship, however, with a smaller magnitude and importance.[12] Real production frictions (higher capital utilisation adjustment costs ψ or lower inverse Frisch elasticity of labour supply σ_l) as well as nominal production frictions (higher price stickiness ξ_p and lower price indexation γ_p) now have all a significant impact in SW03. As in QUEST III, the real frictions lead to a smaller and the nominal frictions to a larger relative response of the cumulative multiplier on output than on inflation.

[12]The values for σ_c below zero and the strange functional forms in Figures 12 and 14 should be ignored since σ_c is strictly speaking only meaningful for positive values. The negative values are a result from the chosen and estimated distribution by Smets and Wouters (2003) and our choice to use posterior moments for the prior distributions.

VII. Conclusion

In this paper we show that the extent to which the size of fiscal multipliers is influenced by the presence of an interest rate constraint significantly depends on the modelling approach. Specifically, we show that when monetary policy is active, the instantaneous fiscal multiplier on output is larger than on inflation. However, when monetary policy is constrained, either due to facing some lower bound or due to a policy decision to keep the rates unchanged, the gap between these two multipliers narrows. In some scenarios the gap even reverts and the fiscal multiplier on inflation becomes larger than the multiplier on output. Our analysis shows that there exists a strong non-linear relationship between the length of the binding constraint and the size of the fiscal multipliers and that this non-linearity is stronger in the case of inflation. A Global Sensitivity Analysis shows that this effect is driven by higher real production frictions, lower nominal production frictions, higher persistence in the fiscal spending cut, and the larger coefficient on inflation in the central bank's interest rate rule.

By investigating four different approaches to modelling the interest rate constraint, we also find that when it is implemented by means of an endogenously-driven constraint at the zero lower bound, the resulting fiscal multipliers are larger as compared to the scenarios where the constraint is anticipated to be imposed exogenously, in particular for the fiscal multiplier on inflation. Nevertheless, the difference in the size of multipliers obtained in these two scenarios is smaller as compared to the difference stemming from two alternative assumptions about the agents' expectations of future monetary policy (anticipated vs unanticipated). In the case of models with forward-looking agents, such expectations matter greatly for determining the size of both instantaneous and cumulative fiscal multipliers as the perfectly anticipated policy leads to a fully front-loaded reaction of the forward-looking agents. It needs to be noted, though, that the instantaneous measure is useful only when the period of constrained monetary policy is correctly anticipated. If agents are surprised about the monetary policy reaction, then the cumulative multiplier becomes much more informative.

Our analysis also illustrates the point of asymmetric effects of fiscal spending shocks implemented when the zero lower bound constraint is binding. The asymmetry of the ZLB, which only allows for interest rate hikes and not for further cuts anymore, implies that a negative fiscal shock at the ZLB extends the constraint's duration while a fiscal stimulus in the same environment results in an increase of the shadow interest rate and thus shortens the period of the binding constraint (see e.g. Erceg and Lindé, 2014). The endogenously-modelled zero lower bound tackles this asymmetry implicitly, i.e. the interest rate remains at the zero level for as long as the accommodation is necessary. A problem, however, arises when the ZLB is modelled exogenously. As the negative spending shock depresses output and inflation, the interest rates must drop below zero for the model to return to equilibrium once the exogenously-determined ZLB ceases to bind. This is obviously inconsistent with the very nature of the constraint. Thus, when studying the impact of fiscal spending cuts at the zero lower bound, the modellers should opt for implementing endogenously-driven constraints. The exogenously-imposed constraints can, in turn, be used to study the effects of a central bank's commitment to keep the rates unchanged for a certain period ("forward guidance").

The above-mentioned results are robust in qualitative terms and hold across the two models we use: QUEST III of the European Commission and the Smets-Wouters model. The Global Sensitivity Analysis of these structural models reveals which parameters are driving our key result of an over-proportional deflationary impact of fiscal spending cuts when monetary policy is constrained. In addition, our analysis does not only highlight the relevance of some modelling and parameter choices when studying the effects of fiscal spending shocks in DSGE models but it also illustrates a novel policy message that should receive more attention from researchers and policy-makers. We present the new concept of a fiscal multiplier on inflation which becomes particularly important when monetary policy is constrained. The over-proportional response of inflation is remarkably stronger than on output. This finding can shed some light on the current situation in the euro area where several years of fiscal austerity have been accompanied by a low inflation environment despite moderate output growth and an accommodative monetary policy stance.

References

Adjemian, S., H. Bastani, M. Juillard, F. Karamé, F. Mihoubi, G. Perendia, J. Pfeifer, M. Ratto, and S. Villemot (2011): "Dynare: Reference Manual, Version 4," *CEPREMAP Dynare Working Papers*, 1.

Bi, H., E. M. Leeper, and C. Leith (2013): "Uncertain Fiscal Consolidations," *Economic Journal*.

Burgert, M. and V. Wieland (2013): "The role of tax policy in fiscal consolidation: Insights from macroeconomic modelling," Economic Papers 502, S. Princen and G. Mourre, European Commission.

Christiano, L., M. Eichenbaum, and S. Rebelo (2011): "When Is the Government Spending Multiplier Large?" *Journal of Political Economy*, 119, 78 – 121.

Coenen, G., C. J. Erceg, C. Freedman, D. Furceri, M. Kumhof, R. Lalonde, D. Laxton, J. Lindé, A. Mourougane, D. Muir, S. Mursula, C. de Resende, J. Roberts, W. Roeger, S. Snudden, M. Trabandt, and J. in't Veld (2012): "Effects of Fiscal Stimulus in Structural Models," *American Economic Journal: Macroeconomics*, 4, 22–68.

Cogan, J. F., T. Cwik, J. B. Taylor, and V. Wieland (2010): "New Keynesian versus old Keynesian government spending multipliers," *Journal of Economic Dynamics and Control*, 34, 281–295.

Corsetti, G., K. Kuester, A. Meier, and G. J. Mller (2010): "Debt Consolidation and Fiscal Stabilization of Deep Recessions," *American Economic Review*, 100, 41–45.

Cwik, T. and V. Wieland (2011): "Keynesian government spending multipliers and spillovers in the euro area," *Economic Policy*, 26, 493–549.

Dieppe, A., A. G. Pandiella, S. Hall, and A. Willman (2013): "Limited information minimal state variable learning in a medium-scale multi-country model," *Economic Modelling*, 33, 808–825.

Eggertsson, G. (2011): "What Fiscal Policy is Effective at Zero Interest Rates?" in *NBER Macroeconomics Annual 2010, Volume 25*, National Bureau of Economic Research, Inc, NBER Chapters, 59–112.

Erceg, C. and J. Lindé (2014): "Is There A Fiscal Free Lunch In A Liquidity Trap?" *Journal of the European Economic Association*, 12, 73–107.

Erceg, C. J. and J. Lindé (2011): "Asymmetric Shocks in a Currency Union with Monetary and Fiscal Handcuffs," *NBER International Seminar on Macroeconomics*, 7, 95 – 136.

Guerrieri, L. and M. Iacoviello (2015): "Occbin: A Toolkit to Solve Models with Occasionally Binding Constraints Easily," *Journal of Monetary Economics*, 70, 22–38.

Orphanides, A. and V. Wieland (1998): "Price stability and monetary policy effectiveness when nominal interest rates are bounded at zero," Finance and Economics Discussion Series 1998-35, Board of Governors of the Federal Reserve System (U.S.).

——— (2000): "Efficient Monetary Policy Design near Price Stability," *Journal of the Japanese and International Economies*, 14, 327–365.

Ratto, M. (2008): "Analysing DSGE Models with Global Sensitivity Analysis," *Computational Economics*, 31, 115–139.

Ratto, M., A. Pagano, and P. Young (2007): "State Dependent Parameter metamodelling and sensitivity analysis," *Computer Physics Communications*, 177, 863–876.

Ratto, M., W. Roeger, and J. i. t. Veld (2009): "QUEST III: An estimated open-economy DSGE model of the euro area with fiscal and monetary policy," *Economic Modelling*, 26, 222–233.

Schwarzmüller, T. and M. Wolters (2014): "The Macroeconomic Effects of Fiscal Consolidation in Dynamic General Equilibrium," Kiel Working Papers 1963, Kiel Institute for the World Economy.

Siemsen, T. and S. Watzka (2013): "Fiscal Multipliers and the Choice of Zero Lower Bound Modeling," CESifo Working Paper Series 4342, CESifo Group Munich.

Smets, F. and R. Wouters (2003): "An Estimated Dynmaic Stochastic General Equilibrium Model of the Euro Area," *European Economic Association*, 1, 1123–1175.

Sobol, I. (1995): "Sensitivity estimates for nonlinear mathematical models," *Mathematical Modeling and Computational Experiment*, 1, 407–414.

Taylor, J. B. (1993): "Discretion versus policy rules in practice," *Carnegie-Rochester Conference Series on Public Policy*, 39, 195–214.

Taylor, J. B. and J. C. Williams (2010): "Simple and Robust Rules for Monetary Policy," in *Handbook of Monetary Economics*, ed. by B. M. Friedman and M. Woodford, Elsevier, vol. 3 of *Handbook of Monetary Economics*, chap. 15, 829–859.

Uhlig, H. (2010): "Some Fiscal Calculus," *American Economic Review*, 100, 30–34.

Wieland, V., T. Cwik, G. J. Müller, S. Schmidt, and M. Wolters (2012): "A new comparative approach to macroeconomic modeling and policy analysis," *Journal of Economic Behavior & Organization*, 83, 523–541.

Woodford, M. (2011): "Simple Analytics of the Government Expenditure Multiplier," *American Economic Journal: Macroeconomics*, 3, 1–35.

Acknowledgements

We thank Robert Beyer, Matthias Burgert, Marco Ratto, Werner Roeger, and the anonymous referee for valuable comments and discussions.

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ISSN	1725-2806 (pdf)	DOI	10.2866/94121 (pdf)
ISBN	978-92-899-2741-3 (pdf)	EU catalogue No	QB-AR-17-031-EN-N (pdf)