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## Global policy at the zero lower bound in a large-scale DSGE model

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**NO 1254 / OCTOBER 2010**

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AT THE ZERO  
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IN A LARGE-SCALE  
DSGE MODEL**

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# GLOBAL POLICY AT THE ZERO LOWER BOUND IN A LARGE-SCALE DSGE MODEL<sup>1</sup>

by Sandra Gomes<sup>2</sup>, Pascal Jacquinot<sup>3</sup>,  
Ricardo Mestre<sup>4</sup> and João Sousa<sup>5</sup>



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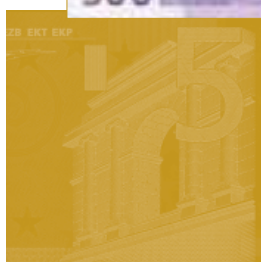
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### Abstract

The purpose of this paper is to analyse whether fiscal policies can alleviate the effects of the zero lower bound (ZLB) on interest rates and if they should be coordinated internationally. The analysis is carried out using EAGLE, a DSGE model of the global economy. We consider that the fiscal shocks are temporary and that fiscal policy retains full credibility at all times. In this setup we find significant non-linearities in a ZLB situation that amplify the effects of fiscal shocks compared to the non-ZLB case. International coordination is helpful but does not play a major role in the results.

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## Non-technical summary

The fact that nominal interest rates cannot be reduced below zero introduces a lower bound to interest rate policy. When interest rates are close to this Zero Lower Bound (ZLB) then policy makers face additional challenges. This is particularly true when an economy faces a recessionary and/or deflationary period and (additional) monetary policy stimulus is warranted but cannot be implemented because the ZLB restriction becomes binding. The inability of interest rate policy to react may prolong the period over which the economy remains in a deflationary environment with clear adverse economic implications.

In the literature, several solutions have been proposed to deal with the ZLB. These include shifting the way monetary policy is conducted (for instance towards exchange rate or price level targeting or conducting unconventional monetary policy measures such as the purchase of illiquid assets, for example long-term bonds which still carry positive interest rates). Another strand of the literature looks at fiscal policy measures as a tool to provide stimulus once interest rates hit the ZLB.

Our paper is related to the later strand of the literature. The focus of this paper is to analyse the use of temporary fiscal policy stimulus to overcome the ZLB situation using a large-scale DSGE model. In addition, we assess if the choice of alternative policy instruments (Government consumption, taxes or transfers) impacts the results. We also aim at assessing whether international coordination of policies matters for the results.

We analyse this issue relying on a state of the art large-scale DSGE model: the EAGLE (Euro Area and Global Economy model). The model is calibrated to approximate the behaviour of the global economy. The model includes 4 blocs: Germany, the rest of the euro area, the US and the rest of the world. In order to simulate the fiscal shocks in a ZLB situation, we first need to drive the interest rates to their lower bound in the model. To do so, we induce a deep global recession in the model through exogenous demand shocks that depress both consumption and investment. As a result, the short-term interest rate, which is assumed to be set by the central bank according to a Taylor rule that responds to inflation and output growth, is driven down

and hits zero, where it stays for several quarters. In a second step we simulate several alternative temporary fiscal stimulus measures that aim at overcoming the ZLB situation. We consider four types of policy instruments. On the expenditure side, we consider an increase in government consumption and in transfers. On the revenue side, we analyse the effects of cuts in income and consumption taxes.

Our results are in line with the literature in that we generally find that under the assumption that fiscal policy remains credible at all times, temporary fiscal stimulus measures are effective in reducing the duration of the ZLB episode. In addition, we find that fiscal multipliers are enhanced when the ZLB restriction is binding, i.e. the response of output and consumption to a fiscal shock is stronger than when the ZLB restriction does not bind. One reason for this amplification is that in a situation when interest rates are positive, a fiscal stimulus that increases GDP and inflation would imply that the central bank would raise interest rates which in turn would have a dampening effect on both economic activity and inflation. Because interest rates are at the ZLB, monetary policy does not react and the effect of the fiscal stimulus is heightened. This amplification effect appears to be more important in the case of the US than in the case of the euro area.

Of the several fiscal instruments, government consumption seems to be among the most powerful instrument for reducing the duration the ZLB in EAGLE. However, both in the euro area and in the US, an increase in Government consumption amplifies the decline in consumption generated by the recessionary shocks. In this respect, the use of a consumption tax leads to a smaller loss in consumption while also significantly reducing the duration of the ZLB. Transfers to households are effective in reducing the ZLB but this depends on the share of non-Ricardian agents (i.e. agents that do not have access to capital markets and therefore cannot use purchases and sales of bonds to smooth the impact of the fiscal shock) in the economy. If all agents were Ricardian, the transfer shock would be ineffective. Finally, the use of an income tax would prolong the ZLB situation, which would be undesirable despite leading to a stronger exit from the recession. The main reason for this result is that a decline in the income tax generates a



strong increase in the supply of labour which leads to lower inflation and therefore results in a longer period during which the economy remains at the ZLB.

It should be stressed that all the measures tested are only temporary and the model is designed to ensure the sustainability of public finances. In addition, we assume that fiscal policy remains fully credible at all times. In fact, a loss of credibility could hamper or even eliminate any possible beneficial effects of such policies, for instance, if they would result in substantially higher risk premia. Finally, a crucial implication of our results that is worth stressing is that it is possible that overly active policies may run the risk of overstimulating the economy (in particular inflation) because the fiscal multipliers rise significantly in a ZLB situation.

# 1 Introduction and motivation

The recent economic and financial crisis was characterised by a steep slowdown that was strongly synchronised across the globe. Central banks used the instruments at their disposal to provide liquidity to banks and significantly cut interest rates to very low levels to counteract downside risks to price stability and, in some cases, to avoid outright deflation. Interest rates have been driven to close to zero in major economic areas which has rekindled the debate about the policy options available in a zero lower bound (ZLB) situation and their impact on the economy.

Several solutions to the ZLB have been put forward focusing on alternative ways of conducting monetary policies, such as price-level targeting (as opposed to inflation targeting) as in Svensson (1999), Svensson (2003), Dittmar, Gavin, and Kydland (1999) or Vestin (2006), or exchange-rate targeting as in Meltzer (1999), Svensson (2001), Coenen and Wieland (2004) or McCallum (2000). Some other threads in the literature have tackled the ZLB with a particular focus on financial environments, such as the analysis of the balance sheet of the central bank, e.g. Jeanne and Svensson (2007) or Auerbach and Obstfeld (2005); or fighting the ZLB through purchase of illiquid assets, e.g. Goodfriend (2000), or the provision of Gesell money, e.g. Goodfriend (2000) or Buiter and Panigirtzoglou (1999). This paper is part of another strand of the literature that looks at the use of fiscal policy instruments as a way to overcome a ZLB situation. Recent examples are the analysis of fiscal multipliers in Romer and Bernstein (2009), Christiano, Eichenbaum, and Rebelo (2009) Cogan, Cwik, Taylor, and Wieland (2009), Bodenstein, Erceg, and Guerrieri (2009) and in Erceg and Lindé (2010).<sup>1</sup>

Our approach consists in conducting a series of simulations of fiscal shocks in a ZLB environment with EAGLE, a large scale global DSGE model.<sup>2</sup> The model is well suited for our goals in many dimensions. First, it can handle global shocks as it has four blocs whose calibration broadly corresponds to Germany, the rest of the euro area, the Unites States and the rest of the world. Second, it includes a rich fiscal sector that allows testing the effects of different fiscal

<sup>1</sup>Note that as in Erceg and Lindé (2010) the duration of the liquidity trap is also here endogenous.

<sup>2</sup>For an analysis of fiscal policy at zero rates in a closed economy model of the US economy see also Eggertsson (2009).

policy instruments. Third, by incorporating forward-looking behaviour and including a mix of Ricardian and non-Ricardian consumers –the latter unable to access financial markets–, EAGLE can be used to analyse the role of expectations which, as argued by Cogan, Cwik, Taylor, and Wieland (2009), matter for the effects of fiscal policy. Note however that the only fiscal shocks analysed in this paper are temporary ones: permanent fiscal measures bring with them complex terminal-condition and transition issues that deserve by themselves a study apart.<sup>3</sup>

The simulation exercises consist in first inducing a deep recession through exogenous demand shocks of sufficient strength to drive the economy (output and inflation) strongly down, which leads to the ZLB via the reaction of monetary policy. We then simulate expansionary fiscal shocks that overcome the ZLB, assess their effectiveness in countering the ZLB and also the scope for international policy co-ordination.<sup>4</sup> Finally, we conduct simulations on the impact of the announced fiscal stimulus packages in a ZLB situation. We confirm the findings in other studies that fiscal policy becomes significantly more powerful in the presence of a ZLB constraint, in particular in the US and especially regarding its effects on inflation. We also find that some fiscal measures can considerably shorten the duration of a ZLB episode. Fiscal shocks generate some spillovers across countries but these are small relative to the direct impact of domestic fiscal measures.

An important aspect of the simulations conducted is that we assume a return to the initial level of public debt. This is assumed to take place through the announcement, together with the fiscal stimulus package, of a fiscal consolidation on exit. Agents believe the announcement and expect a future fiscal tightening, i.e. a period of below-baseline fiscal deficit, to bring debt down.<sup>5</sup>

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<sup>3</sup>For an analysis of fiscal multipliers associated with both temporary and permanent measures see for example Coenen, Erceg, Freedman, Furceri, Kumhof, Lalonde, Laxton, Lind, Mourougane, Muir, Mursula, de Resende, Roberts, Roeger, Snudden, Trabandt, and in't Veld (2010). Other issues of relevance that will not be touched upon in this paper in the interest of brevity are the stability and equilibrium “pathologies” issues tackled elsewhere in the literature, see e.g. Benhabib, Schmitt-Grohe, and Uribe (2001), Benhabib, Schmitt-Grohe, and Uribe (2002), Buiter and Panigirtzoglou (2003), Alstadheim and Henderson (2006) or Christiano and Rostagno (2001) in a rational-expectations environment, or in McCallum (2000), Evans and Honkapohja (2005) in a learning one; nor the issue of the effects of gradual monetary policies as opposed to activist ones, see e.g. Goodfriend (1991), Woodford (1999), Reifschneider and Williams (2000) or Gaspar, Smets, and Vestin (2007).

<sup>4</sup>Fiscal exit strategies from the ZLB through boosting the economy have also been analysed in Benhabib, Schmitt-Grohe, and Uribe (2001) and Benhabib, Schmitt-Grohe, and Uribe (2002), in the same spirit as done in this paper but using small-scale, purpose-built models.

<sup>5</sup>Note that the unwinding of the fiscal stimulus described later in the text does not end fiscal moves: the fiscal rule in EAGLE imposes a long-lasting tightening (using *lump sum* taxes) to ensure a return of debt to its

This policy does indeed help in boosting the effects of the initial fiscal stimulus, see Corsetti, Kuester, Meier, and Müller (2010). The solvency of the Government is in this way always assured in the simulations. It should be stressed that the fiscal multipliers could be significantly reduced or even change sign if the expansionary policies lead to a loss of credibility of the fiscal authority.<sup>6</sup>

The text is structured along two broad lines: firstly, an exposition of how a recession leading EAGLE to the ZLB was engineered; secondly, an analysis of alternative fiscal measures aimed at avoiding or shortening the ZLB episode. Section 2 presents briefly the model, followed by section 3 which explains the steps taken to make EAGLE hit the ZLB. Section 4 then explores the alternative fiscal exercises that form the bulk of the analysis. Section 5 tackles the related point of comparing the resulting fiscal multipliers when the ZLB has been hit and in more normal circumstances. Section 6 builds on the previous analysis to assess the impact on EAGLE of existing fiscal programmes. Section 7 concludes.

## 2 The model: a brief presentation of EAGLE

The EAGLE (Euro Area and the Global Economy) model is a multi-country DSGE model of the euro area in the world economy, described in detail in Gomes, Jacquinot, and Pisani (2010). In the euro area monetary union we differentiate two blocs: Germany and the rest of the euro area. The other two blocs in the model are the US and the rest of the world.

Each country/bloc comprises households, firms and a monetary and fiscal authority. Each household is infinitely lived, consumes a final good<sup>7</sup> and supplies labour to all domestic firms in a monopolistic market. We assume wages are sticky *à la* Calvo (1983), with indexation. Households decide how to allocate their time between work and leisure. A fraction of households does not have access to capital markets and has to finance consumption exclusively through disposable labour income. The remaining households own the domestic capital stock, which

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pre-simulation level.

<sup>6</sup>The empirical estimates of fiscal multipliers show considerable heterogeneity, with a number of studies showing negative multipliers for some countries, see for example Perotti (2005). Spilimbergo, Symansky, and Schindler (2009) provide a recent survey on fiscal multipliers.

<sup>7</sup>We assume habit persistence in consumption.

they rent to domestic firms that they also own. They buy and sell two bonds, one issued domestically in domestic currency and the other is an international bond issued in zero net supply worldwide. When households sell or purchase the international bond they pay a premium to financial intermediaries. The size of this premium is a function of the aggregate net asset position of the country and therefore can be seen as reflecting the cost of intermediation. In the case of the monetary union, we assume there is a bond denominated in the common currency which is traded across the countries member of the union. Again this bond incorporates an intermediation cost with the purpose of guaranteeing the stationarity of the model.<sup>8</sup> Labour and physical capital are immobile internationally. The market for capital is competitive, and capital accumulation is subject to adjustment costs.

In what regards the production side, there are firms producing final goods and a continuum of differentiated intermediate goods. In each country there are three final goods produced in a perfectly competitive market: a consumption good, an investment good and a public good. Consumption and investment final goods are produced by using all available intermediate goods as inputs using Constant Elasticity of Substitution (CES) technology and allowing for home bias, whereas the public good is a composite of only non-tradable intermediate goods. There are many varieties of intermediate goods, each produced by a single firm under monopolistic competition. Prices are sticky *à la* Calvo (1983), with indexation. Each intermediate good is produced by using domestic labour and domestic capital, combined with a Cobb-Douglas technology. Intermediate goods are either non-traded or traded internationally. Final goods are produced with non-traded intermediate goods, domestic traded goods and imported traded goods. Imports are subject to short-term adjustment costs that temporarily lower the response of demand to changes in relative prices. There is international price discrimination since firms set prices in the currency of the importing country.

The government purchases the public good and finances its expenditures with public debt

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<sup>8</sup>The introduction of the euro area bond is a technicality, related to the need of imposing that the same interest rate level holds in both regions in the monetary union and that the bilateral nominal exchange rate between these regions is constant. Note that this cost does not take into account any aspect linked to sovereign risk and so the debt of all the countries in the Union is (and is so perceived by the markets) as default-free. For more details on the monetary union please see Gomes, Jacquinot, and Pisani (2010).



and taxes on the domestic private sector. There are lump-sum and distortionary taxes, levied on the price of consumption, the rental rate of capital and wages. Standard fiscal rules that target the level of public debt ensure fiscal stability in each bloc. The monetary authority sets the national short-term nominal interest rate by means of a Taylor-type interest rate rule. In the case of the euro area, the central bank sets the interest rate for all the country members on the basis of area-wide indicators. For the simulations in this paper, we also assume that interest rates are bounded from below at zero.

Regarding the calibration of the model, the steady-state ratios have been set to match actual national accounts data and the key behavioural parameters have been chosen using information from the existing literature, some of which are invariant across countries while others have been modified to match country-specific information, such as the steady-state ratios of nominal domestic demand components to GDP. The bias towards domestic tradable goods and the weight of non-traded goods in the consumption and investment baskets are set to match the shares of imported and services goods in the considered economy, given the values of the intratemporal and intertemporal elasticities of substitution.<sup>9</sup> Nominal and real rigidities allow to produce realistic dynamic adjustment patterns. Monetary policy authorities are assumed to target inflation. We assume identical calibration of the Taylor rules in all the blocs.<sup>10</sup> For all blocs, the inflation target is set at 2 percent. The calibration of the fiscal policy rule is standard. The parameter measuring the reaction of taxes to public debt is set to achieve debt sustainability and hence model stability.

### 3 Hitting the bound

The goal of this section is to introduce the basic mechanism used in EAGLE to induce a recession and deflation and drive the model into the ZLB constraint. In the exercise, it is assumed that a sequence of unexpected shocks hit the global economy for as long as needed to ensure that the

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<sup>9</sup>The calibration is fully reported in Gomes, Jacquinot, and Pisani (2010).

<sup>10</sup>The benchmark calibration of EAGLE assumes a smoothing parameter of 0.87, parameter on inflation of 2 and parameter on output growth of 0.77. For this paper we change the rule somewhat, as explained in the next section.

ZLB is hit.<sup>11</sup> For obvious reasons, domestic demand shocks were preferred: domestic on account of the muted international spillover effects common to most DSGE models; shocks to demand to ensure that inflation and output both decrease, a reflection of the current situation.

In practice, consumption and investment are shocked for 6 consecutive periods. Agents correctly forecast the results of each shock as they hit the economy, but are unaware of the future shocks about to hit. The number of shocks is sufficient to drive the interest rate to the bound for a sufficiently long period of time—in practice, for around a couple of years, depending on the country. The situation is similar to one in which factors not included in the model affect agents' confidence, such as a sequence of bad news regarding the financial health of the banking sector. Since EAGLE does not include a fully-fledged banking sector, this behaviour can be approximated by assuming that consumers and firms' confidence erodes gradually over the period.

The literature has touched upon the exact level of the lower bound on interest rates, see e.g. Yates (2004), McCallum (2000) or Buiter (2005), which may differ slightly from zero due to potential costs from holding money or gains from using it. Furthermore, it may be argued that central banks tend to recoil from setting their policy rates at exactly zero, for reasons of financial stability. But for the sake of simplicity, the definition adopted in the exercises below has been for the lower bound to lie exactly at zero.<sup>12</sup>

Compared to the original version of EAGLE in Gomes, Jacquinot, and Pisani (2010), the parameters in the monetary policy rules were also changed, in order to ensure a faster response of policy to the developments in the economy: the parameter attached to the lagged interest rate in the rules was set to zero. The rationale for this change rests on the idea that central banks change their policy faster in view of the extreme circumstances faced. This change has led to a faster reduction in interest rates and an earlier onset of the ZLB condition, in reflection of actual events in 2008/2009. Needless to say, this is just a technical device used in the simulation, as

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<sup>11</sup>Shocks come in sequence, instead of as a single very large shock, to avoid an immediate entry into the ZLB. The alternative would have led to less room for policy analysis, such as the analysis of pre-announcement effects.

<sup>12</sup>The ZLB was introduced into the model by using the maximum function in the policy rule, such that a zero rate would be returned in case the rule would imply a negative number.

opposed to an actual policy recommendation.

To ensure a smoother exercise, the steady state real interest rate was set at 1% p.a., as against 3% in the standard calibration of the model. This change eased the numerical difficulties of the exercise, but is also a reflection of the average real rate over the period 1999 to 2009, which hovers slightly above 1%. In the period, the 3-month interbank rate, the most common proxy for policy rates used in DSGE models of the euro area, averaged around 3.3%, while HICP inflation averaged around 2.1%.

Shocks are assumed to take place in every bloc in the model, simultaneously, over the said 6 consecutive quarters. The shocks are unexpected, i.e. agents each time think the sequence of bad news is over. The shocks are similar across periods, and amount to roughly 4% of consumption and 0.2% of Tobin's Q *ex-ante*, both reflecting an assumed drop in confidence by agents. Results will be presented and discussed for alternative configurations: firstly, with and without the ZLB condition implemented in the model, to assess its impact; second, assuming the fiscal shocks are implemented only in one economic area (euro area or the US) but not in the other blocs, to assess inter-bloc spillover effects.

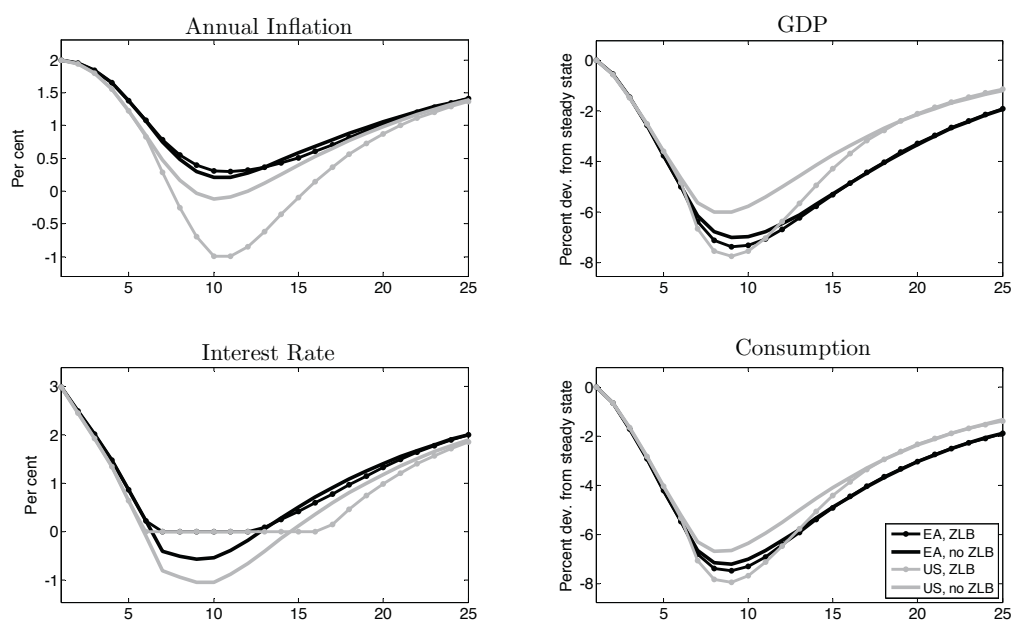
### 3.1 Results

The results of the recessionary shocks are reported in Figure 1, which includes the impact in euro area (EA) and in the US annualised consumer price inflation (in percentage points), GDP (in % deviation from the steady state), the short-term interest rate (in percentage points) and consumption (in % deviation from the steady state). The figure starts in the period previous to the shock and shows results for the first 6 years, i.e. the pre-shock period plus the following 24 quarters. The figure shows the benchmark 6-quarter global recession shock in the presence and in the absence of the ZLB. The simulation without the ZLB imposed (negative rates are allowed) helps in highlighting the impact of the ZLB restriction, but in practice is an impossibility.

Starting with the euro area, the paths followed by inflation, output and consumption do not differ much in the ZLB and the no-ZLB cases, even though in the latter case interest rates



Figure 1: Global and EA recession and the ZLB



actually become negative. However, it should be noted that the shock we are imposing on the model is rather large and so interest rate policy alone (assuming the central bank continues to follow the same monetary policy rule) would not be able to counteract the induced recession. Interestingly, the results for the US suggest that the same global shock would imply a larger decline in real economic activity and especially in the rate of change in prices, which actually becomes negative. The duration of the ZLB episode would be longer in the case of the US than in the euro area. Thus, it seems that the “costs” of the ZLB restriction are higher in the case of the US than in the case of the euro area.<sup>13</sup>

Another interesting fact is that the model smoothly returns to the steady state in all cases.

The model thus shows no explosive behaviour in the ZLB, a theoretical possibility, see Benhabib,

<sup>13</sup>The source of this discrepancy was tracked to be caused by the higher nominal persistence in the euro area. Results for the euro area matched the US results shown when the Calvo parameters in the euro area were brought down to the US levels. Note that the ZLB is avoided (just) when running the same recession shock in the EA only, i.e. without spillover effects from the rest of the world. Spillover effects in the model, described as small later, are nevertheless significant.

Schmitt-Grohe, and Uribe (2002), and seems instead to enter a region of indeterminacy.<sup>14</sup> It seems reasonable to expect that expectations are one of the main factors behind the exit from the ZLB. The fact that agents expect inflation to be positive and output to return to more normal growth eventually would guarantee, under indeterminacy, an exit from the ZLB condition at some stage, with neither fiscal nor monetary policy directly doing the job. In a sense, the outcome is achieved through managing agents' expectations.

A caveat applies here: revisions of beliefs by agents (or outright panics) could induce an explosive deflationary spiral in the model. Since monetary policy can no longer steer the economy through changes in interest rates, any expectations of continued deflation would go unchecked. The fact that EAGLE recovers by itself from a ZLB episode must not be construed as implying a policy prescription for monetary passivity. The model embodies full monetary policy credibility, i.e. a credible inflation target, but does not include mechanisms to enforce it in a ZLB episode. Fiscal policy may help in such a situation, but explicit additional monetary policy action may be required, such as e.g. liquidity measures or changes to the policy target (see literature cited in the introduction for exercises of this kind).

## 4 The fiscal reaction

To assess how fiscal policy can counteract the induced recession, we have considered a set of stylised fiscal shocks affecting each one a specific budgetary item: Government consumption, consumption tax rates, transfers and wage income tax rates. Stylised simulations allow the isolation of the effects of fiscal policies, whereas actual fiscal programmes normally include a mix of measures whose impact in isolation is difficult to disentangle. Furthermore, they allow for an easier understanding of alternatives in fiscal planning. An analysis of actual (complex) fiscal plans is left for section 6. In this section, instead, we explore simple exercises and, as

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<sup>14</sup>It is not easy to ascertain whether it is the case that the model is indeterminate. One test made was to calculate the dynamic roots of the model linearised around a steady state in which the ZLB held—by either setting the terminal inflation rate sufficiently low to force a terminal null nominal rate, or by artificially increasing the threshold for the ZLB above zero. The roots indicated that there were 3 indeterminate conditions, in accordance with the number of independent monetary policies in the model. The model under standard conditions is stable and determinate.

a complement, we study the impact of asymmetric implementation of policies, i.e. subjecting different blocs in the model to different fiscal shocks.<sup>15</sup>

Note that the simulations reported below are more complex than the simple shocks normally used to report fiscal multipliers.<sup>16</sup> Note also that no permanent fiscal shocks are reported, these being out of the scope of this paper. Permanent fiscal shocks are documented elsewhere (see Coenen, Mohr, and Straub (2008) or Cogan, Cwik, Taylor, and Wieland (2009) for recent exercises) and result in significant terminal-condition issues and transition effects, from one steady state to another, that do not shed light on the interaction between the ZLB and fiscal policy.

One important element worth mentioning is the type of fiscal rule used in the exercises to stabilise the model, i.e. to ensure proper return to the steady-state. The rule used is the standard one in EAGLE, which stabilises debt and deficit by endogenising lump-sum taxes for Ricardian consumers. This implies, in practice, that fiscal policy experiments are not impaired by the effect of rule-induced changes in distortionary taxes.<sup>17</sup>

Finally, it should be noted that we assume that government actions have no effects on the risk premium for public-sector debt. If this assumption were to be dropped, the effects of fiscal policy reported in the next sections would be reduced.

#### 4.1 The raw exercise

In this section, we assume that all countries/blocs in the model implement simultaneously the same simple fiscal measure (i.e., different expenditure increases or tax decreases) as a response to the global recession. The simultaneous global fiscal shocks, all designed to represent *ex-ante* around 2.5% of GDP, are:

- An increase in Government consumption;

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<sup>15</sup>Note that we have conducted extensive sensitivity analysis, some reported below. One worth noting at this stage is the similarity of results across blocs when the value of key parameters were made equal in the euro area and US blocs, in particular regarding the effectiveness of the fiscal measures in exiting the ZLB.

<sup>16</sup>Standard fiscal multipliers for EAGLE can be found in Gomes, Jacquinot, and Pisani (2010).

<sup>17</sup>The results did not change substantially when a fiscal closure rule in terms of wage-income taxes, which are distortionary, was used.

- A decrease of taxes to consumption;<sup>18</sup>
- An increase in transfers to households;
- A decrease in the income tax rate (which in EAGLE falls mainly on wage income).

Note that a decrease in Social Security contributions paid by households is not reported due to the similarity of the results to those of the income tax simulation.

One aspect of the simple exercises is an analysis of announcement effects. It is well-known that the implementation of fiscal measures takes some time, implying that they are normally announced some time before they are enacted. This is a feature worth exploring in EAGLE. The simple exercises reported below have thus been implemented with a specific time frame: it is assumed that fiscal authorities announce the measure in the fourth period of the recession, when the first four shocks have hit the economy but two others remain in the pipeline, unknowingly to the fiscal authorities.<sup>19</sup> Furthermore, the actual implementation is credibly announced to start one period after the announcement, i.e. in the 5th period.<sup>20</sup> The policy is announced to be slowly withdrawn after 12 periods of it being active, with a withdrawing rate afterwards of 20% of the original measure per period. This gradual fading away of the measure serves the purpose of smoothing out the exit from policy in the results reported, but has otherwise no substantive implication.

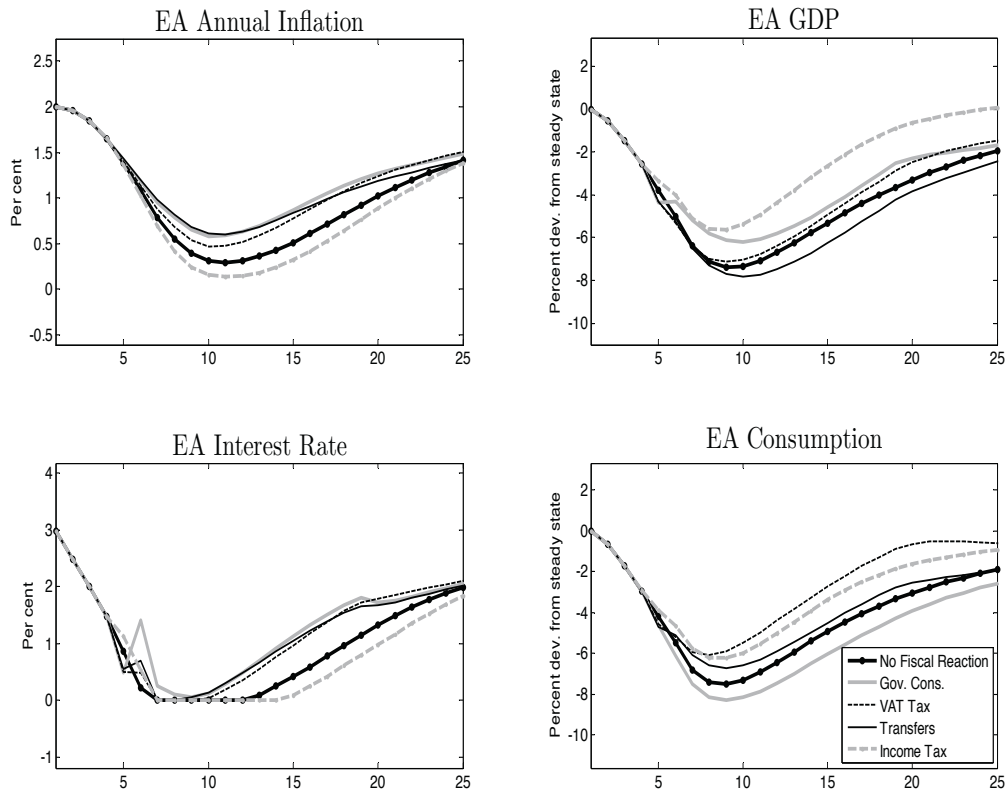
Thus, agents in the model know at that time about the first four recession shocks and the entire history of future policy. When the subsequent recession shocks hit (up to a maximum of 6), they revise their expectations regarding the overall impact of the demand shock, but their view of fiscal policy is not changed. Agents are assumed to be rational, so they expect hits to the ZLB whenever the condition is relevant. They also expect a return to normal, non-ZLB

<sup>18</sup>In the calibration of the steady state level of the consumption tax rates we follow Coenen, McAdam, and Straub (2008). In the case of the euro area the tax on consumption corresponds to the VAT rate while in the case of the US it corresponds to the average of state plus maximum local sales tax rates. For the sake of simplicity, we will henceforth refer to the US consumption tax as VAT tax.

<sup>19</sup>This choice is obviously arbitrary. It was adopted because delaying the announcement to the fifth period implied that the fiscal reaction would be implemented with the economy deeply in the ZLB, which might have blunted the analysis.

<sup>20</sup>Longer pre-announcement periods were also tested, leading to stronger quantitative impacts of pre-announcing policies. Qualitative results, though, were in line with those reported.

Figure 2: Fiscal reactions to the ZLB recession: euro area



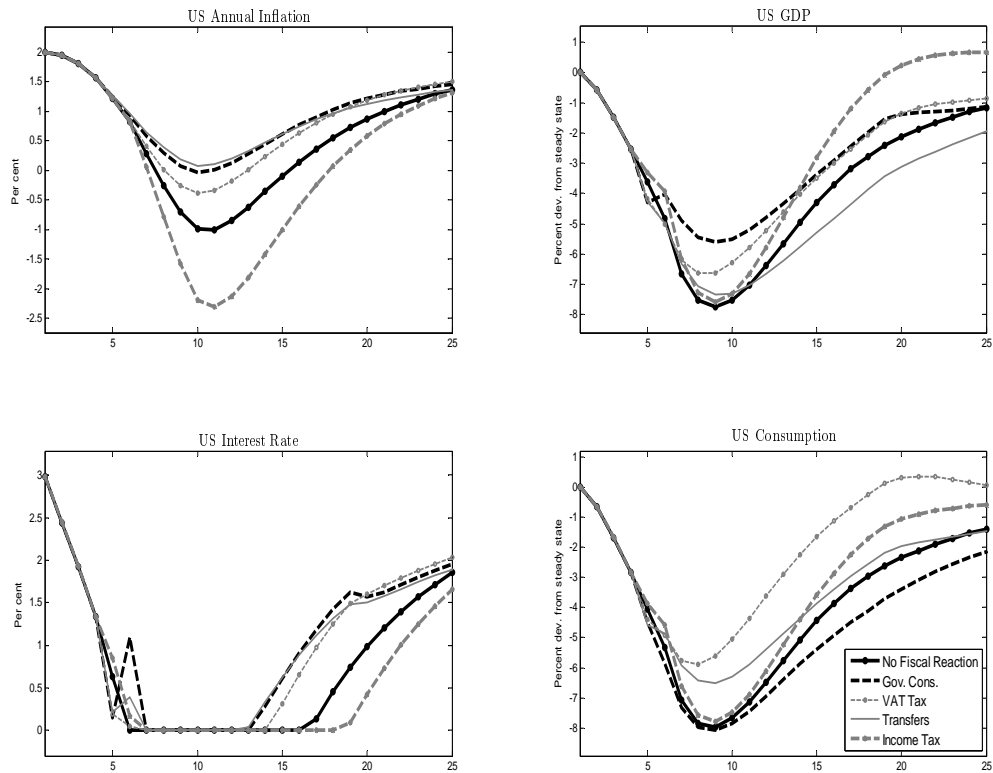
conditions eventually.

The simulation results for the euro area and the US are included in Fig. 2 and 3, and are explained below in specific sub-sections.

### Government consumption shock

The government consumption shock is fairly successful in bringing the economy back from the doldrums. The ZLB is no longer reached in the case of the euro area and in the case of the US the time spent in the ZLB is basically halved, which brings the benefit of a shorter deflationary period. Furthermore, it affects directly demand and GDP. Accordingly, inflation is also significantly

Figure 3: Fiscal reactions to the ZLB recession: US



impacted. The counterpart is the heavily negative impact on consumption, even though 25% of consumers are assumed to be financially constrained. As in Coenen and Straub (2005), the positive effect the increased demand has on non-Ricardian consumers is mostly offset by the deep negative impact on Ricardian consumers. The final multiplier is thus negative for consumption.

Note that announcement effects are clearly visible, as indeed in the other simulations. The most notable effect is in the interest rate itself, which dips on announcement before briefly spiking on implementation of the policy. This behaviour follows, with some amplification, the movements in GDP, itself a consequence of the change in government consumption and, to a much lesser extent, trade. Private consumption, on the other hand, is quietly smoothed out over this period.

### **VAT tax shock**

The decrease of VAT has a more muted impact on the overall economy. Time spent in the ZLB is shorter than without the policy action and GDP is positively affected, hardly a surprise, but only very gradually. More noteworthy is the effect on consumption which, compared to the baseline, increases markedly in the euro area and the US once the policy is actually implemented. In both economic areas it is the fiscal policy measure that best counteracts the fall in consumption, though not of GDP. Contrary to what could be expected, inflation is higher than the baseline, reflecting a relatively powerful demand-boost effect able to more than offset the impact of the reduction in VAT.

### **Transfers**

The model includes two types of transfers, according to the type of consumer affected by them. One part is paid to Ricardian agents and the other to non-Ricardian ones; the shares are such that the latter receive per head 2 times the amount paid to the former. Since transfers are a lump-sum payment, Ricardian agents pay no notice of temporary shifts to them, whereas non-Ricardian agents do because they have to spend or save them. This implies that transfers will be able to affect outcomes only to the extent that they are received by non-Ricardian consumers.

The impact of the change in transfers on output is relatively complex: in the case of the

euro area GDP is in fact negatively affected, while the impact on consumption is in the middle range of the simulated fiscal measures. This result comes about because of the differing impact of the shock on the two types of consumers. Non-Ricardian consumers increase their demand and push the activity strongly upwards, which in turn implies that policy makers need to tighten policy a bit earlier than in the other cases. This obviously has a negative effect on Ricardian consumers and investors, who face higher interest rates than otherwise. Total consumption is only mildly affected because of a composition effect: it embodies a strong positive reaction from non-Ricardian agents and a strong negative reaction from Ricardian ones.<sup>21</sup> The important drop in GDP is caused by a sizeable negative reaction of investment. Inflation, on the other hand, is slightly higher than in the other simulations. Finally, announcement effects are also visible but more muted than in the case of the Government spending shock.

### **Income tax**

In contrast to the other fiscal measures, the income tax simulation does not help in accelerating the exit from the ZLB: in fact, it lengthens it. The reason for this is that the reduction in income tax leads to deflationary pressures in the model as it turns out to be a supply-side shock. In fact, the reduction of income taxes amounts to a negative cost-push shock in the case of firms (i.e. it decreases the marginal costs of firms) and an incentive for households to raise their labour supply. The net effect is that output expands much more than in the other exercises, especially on exit from the ZLB. The expansion of supply has a negative impact on inflation, which sinks (getting back to deflation in the case of the US). Given the assumed monetary policy rule, the interest rate ends up returning to the ZLB. Thus, this policy is not an effective way to overcome the ZLB episode as it heightens the risk of prolonged deflation.<sup>22</sup> The announcement effects for this shock are muted.

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<sup>21</sup>This composition effect is a robust feature of EAGLE, such that changes in the share of non-Ricardian consumers brings little in terms of changes in the reaction of *total* consumption. The only exception is precisely the transfers simulation, totally ineffective if there are no non-Ricardians

<sup>22</sup>On the perils of labour tax cuts when interest rates are bounded at zero see also Eggertsson (2009).



## 4.2 Asymmetric fiscal measures

We continue the analysis of the impact of fiscal measures in a ZLB framework by simulating asymmetric configurations of fiscal measures, i.e. we no longer assume that all blocs in the model implement simultaneously the same fiscal measures. Instead, we now investigate the impact of asymmetric, though still stylised, fiscal measures. In particular, we simulate the same global recessionary shock and assume that there is a gradual decrease of the VAT tax rate in the euro area, leading to a decline in tax revenue of around 2.5% of GDP *ex-ante*, while in the US and the Rest of the World there is no change in fiscal policy. We also simulate a gradual increase in government consumption of 2.5% of GDP *ex-ante* in the US assuming that the euro area and the rest of the world do not take any fiscal measure.<sup>23</sup> The timing and size of the temporary recessionary shocks and of the temporary fiscal measures is the same as in the previous section.

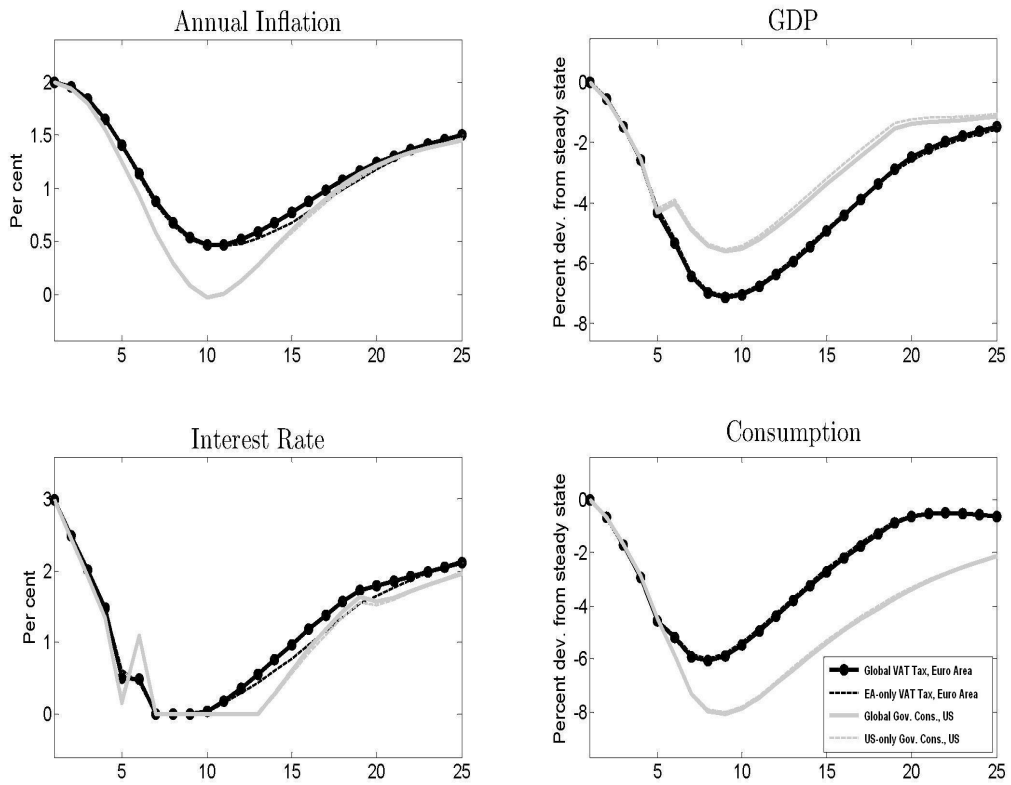
Results are shown in Fig. 4. The first thing to stress in the figure is that the responses of the variables in each bloc are similar to the ones in the case of a unilateral fiscal response, implying that the spillovers of the fiscal measures across blocs are relatively small. Therefore, there are costs of domestic inaction, as the benefits to one bloc of fiscal measures in another bloc are limited. The increase in government spending is more effective in shortening the time spent in the ZLB. Also, GDP presents a bigger fall in the euro area than in the US. However, in the US the increase in government spending crowds out private consumption, aggravating the decline in consumption induced by the recessionary shocks, while the opposite happens in the euro area, where the decrease in the VAT tax rate stimulates consumer purchases, as seen in the previous section.

Annual inflation shows a more pronounced drop in the euro area and goes into negative territory for one year, while in the US the fiscal stimulus allows this bloc to escape having negative annual inflation rates.

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<sup>23</sup>Alternative configurations were tested, with little change in the interpretation of results. In presenting results, we chose a Government consumption shock for the US and a VAT tax shock for the euro area because of the higher importance of VAT taxes in the fiscal stimulus packages for the latter.

Figure 4: Coordinated and uncoordinated fiscal reactions



## 5 Fiscal policy multipliers in the ZLB

As shown in the previous sections, fiscal policy can play a role in overcoming the ZLB, in particular via its effect on demand. In this section, we take a different perspective: we analyse if and how the usual fiscal multipliers are affected when the economy is in a deep recession or when the ZLB is binding. The idea that fiscal multipliers are higher in the ZLB is recurrent in the literature (see e.g. Christiano, Eichenbaum, and Rebelo (2009)), and is worth exploring in EAGLE.

The exercise is twofold. First, we assess whether the economy's responses to fiscal shocks in times of economic recession differ from those obtained under more "normal" circumstances. Second, we evaluate the responses in a situation where the economy temporarily hits the ZLB, based on the exercise in the previous sections. If the model was entirely linear, the fiscal multipliers should not change when the starting conditions change. To the extent that they differ, they point to important non-linearities in the model.

If EAGLE was a strongly non-linear model, any change in the initial conditions of a fiscal shock would change its impact. There lies the interest in comparing the impact of a given fiscal shocks with and without a pre-existing recession. If inflation and output are initially significantly below the steady state due to the induced recession, they may respond differently to the fiscal shock. A second source of non-linearity is the ZLB itself. When the ZLB is hit, the interest rate ceases to react and so the macroeconomic impact of fiscal shocks is likely to change relative to the non-ZLB case. In summary, non-linearities may become apparent either by the cyclical position of the economy or by the loss of monetary policy flexibility under the ZLB.

The exercise conducted consists in comparing the impact of the government consumption shock described in the previous sections, conditioning on the presence or absence of the ZLB. We have chosen to carry out the analysis for the government consumption shock for three main reasons: in the first place, it is among the most powerful fiscal shocks analysed previously; in the second place, it is the most common in actual fiscal programmes; finally, its impact on the economy is among the simplest to understand in models like EAGLE.

In order to identify these effects we conduct three simulations. In the first simulation (simulation 1) we run a Government consumption shock equal to the one in section 4 (2.5% of GDP *ex ante*), but this time starting the simulation assuming that the economy is at the steady state. In simulation 2, we run the same fiscal shock but assume that there is an additional global recession shock equal to the one considered in section 3.<sup>24</sup> In this simulation we assume an unconstrained monetary policy rule, i.e., the policy interest rate can become negative. Finally, simulation 3 replicates the results in section 4, i.e. a global recession shock plus a fiscal shock in the presence of ZLB constraints.

Figures 5 and 6 present the results of the exercise. The figures again include panels for inflation, output, the interest rate and consumption for the three simulations. Note that as we are computing the effect of the fiscal shock under different circumstances, in each simulation we compute the deviation of each variable from its specific baseline, i.e baseline paths differ across simulations. In each case, the baseline is similar to the simulation at hand once the fiscal shock has been withdrawn. The baseline is thus the steady state in simulation 1, the response to a global recession shock with an unrestricted interest rate in simulation 2, and the response to a global recession shock with the ZLB restriction imposed in simulation 3. This way we are able to isolate the specific effect of the fiscal shock in each simulation, which allows us to compute the fiscal multiplier.

The results in Figures 5 and 6 show a remarkable degree of linearity in the model for the first two simulations, both in the case of the euro area and the US. In both areas, the two lines overlap to a very large extent, which implies that, according to the model, the impact of a fiscal shock on GDP and inflation in a deep recession is similar to that in a neutral cyclical position. On the other hand, the presence of the ZLB constraint leads to large non-linear behaviour, which is more marked in the case of the US. This can be seen in the departures of inflation, output and consumption seen in the third simulation, compared with the other two. This departure largely coincides with the period in which the nominal interest rate is constrained by the ZLB. This shows

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<sup>24</sup>It should be noted that the main exercise in the text assumes a close to 8% drop in GDP in the euro area and a similar impact elsewhere, past anything seen since the Great Depression. This seems to be an excellent benchmark for the impact of initial conditions on the simulation.

Figure 5: Government consumption multipliers in different situations: with and without recession, with and without the ZLB - Euro area

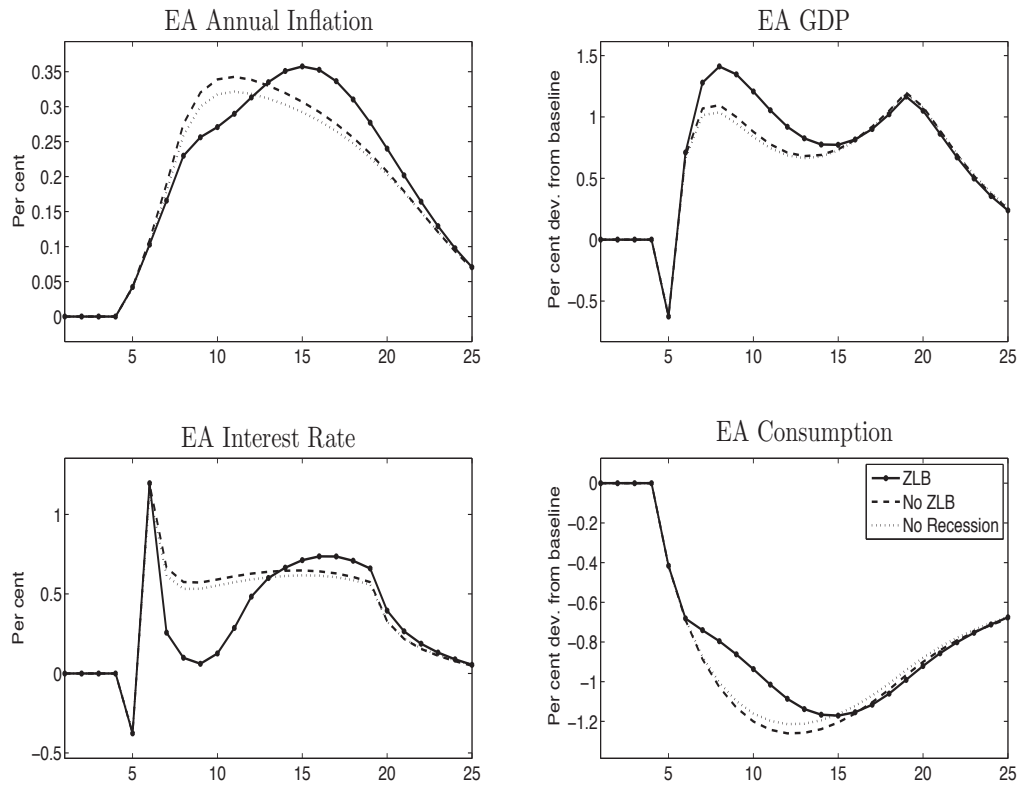
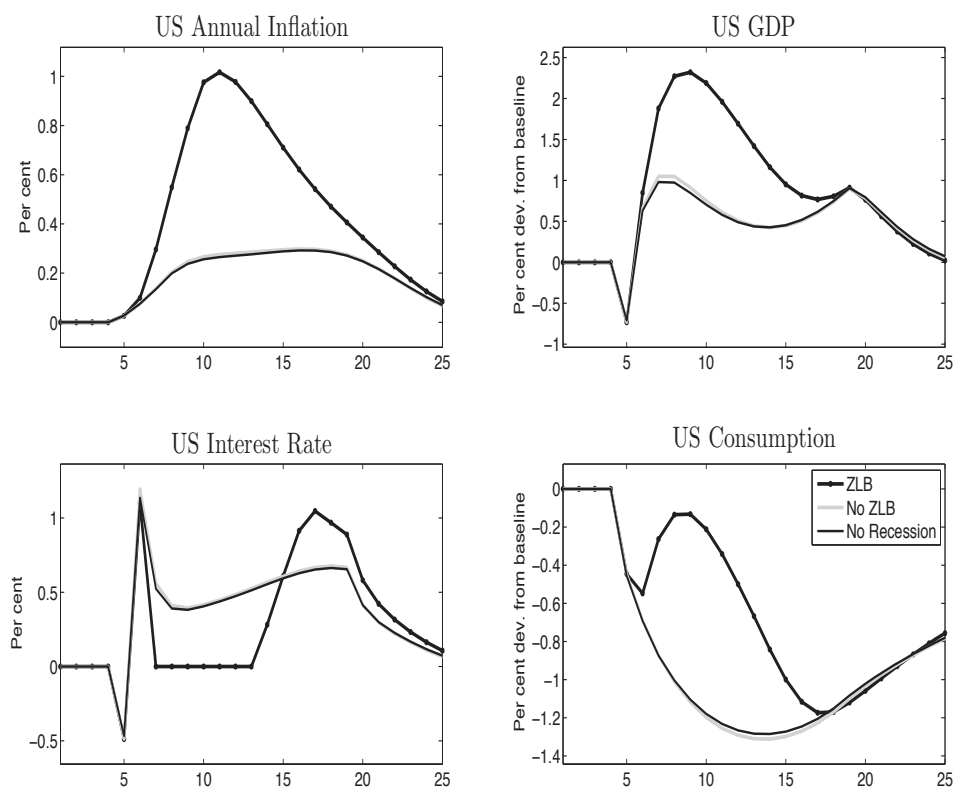


Figure 6: Government consumption multipliers in different situations: with and without recession, with and without the ZLB - US



that fiscal policy becomes particularly powerful in a ZLB situation, with a fiscal shock having a much stronger upward impact on GDP and a less negative impact on private consumption. On the other hand, the inflationary impact of the fiscal shock is heightened, particularly in the case of the US.<sup>25</sup> Thus, in EAGLE, the ZLB does indeed affect the size of the fiscal multipliers and more so in the US than in the euro area.

## 6 The fiscal programmes

In this section we simulate the effects of announced fiscal stimulus programmes in a ZLB context. To do so we rely on the estimates in Manteu and Martins (2009) which are based on the OECD's assessment of the fiscal packages published in OECD (2009).<sup>26</sup> The plans include measures for the euro area (split between Germany and euro area less Germany), the US and a bloc aggregating Japan and the UK.<sup>27</sup>

The size of the fiscal packages had to be adapted to the EAGLE model, which implied some judgment and the exclusion of some of the announced measures. The details of the shocks and the choice of the relevant variables in EAGLE are shown in Table 1. All values are in percentage deviation from steady state GDP. The stimulus package in the US is the largest, with stimulus measures averaging over two percentage points of GDP in the years 2009 and 2010. Germany's fiscal boost is the second largest in proportion of GDP, with measures amounting to 1.3 and 1.5 percentage of GDP in 2009 and 2010 respectively. Fiscal measures in the rest of the euro area and in the rest of the world bloc (which in practice corresponds to the UK and Japan) are less sizeable and are mainly concentrated in 2009. In the case of the US, the stimulus package considered does not contain any measures affecting social insurance contributions or consumption taxes, contrary to those of the other blocs.

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<sup>25</sup>Other fiscal shocks lead to the same conclusion. The higher non-linear behaviour of the US bloc was found to be linked to its lower price persistence, which increases the time spent in the ZLB, as already mentioned before. Results of these alternative exercises are not shown in the interest of brevity.

<sup>26</sup>It should be noted that the the implementation of the discretionary measures may have differed somewhat from the original plans. In addition, some governments have recently announced plans for fiscal consolidation but this issue is beyond the scope of this paper and so we leave it for further research.

<sup>27</sup>The measures considered include only discretionary measures announced or implemented up to March 2009 which are considered to be taken in response to the crisis.

	Euro area excl. Germany		Germany		US		UK and Japan	
	2009	2010	2009	2010	2009	2010	2009	2010
<b>Revenues</b>								
Tax on individuals	0.19	0	0.13	0.27	0.49	1.07	0.03	0.05
Tax on businesses	-0.01	0.03	0.09	0.19	0.38	0.22	0.05	0.08
Social insurance								
Employees	-0.01	-0.01	0.29	0.37	0	0	0.03	0.01
Firms	0.01	0	0	0	0	0	0.04	0.02
Consumption taxes	0.01	0	0.03	0.03	0	0	0.2	0.07
<b>Spending</b>								
Public consumption	0.28	0.04	0.51	0.52	0.9	1.06	0.48	0.08
Transfers	0.11	0.03	0.24	0.1	0.37	0.12	0.36	0.02
Total (in % of GDP)	0.59	0.1	1.28	1.49	2.15	2.48	1.18	0.33

Table 1: Size of the fiscal packages

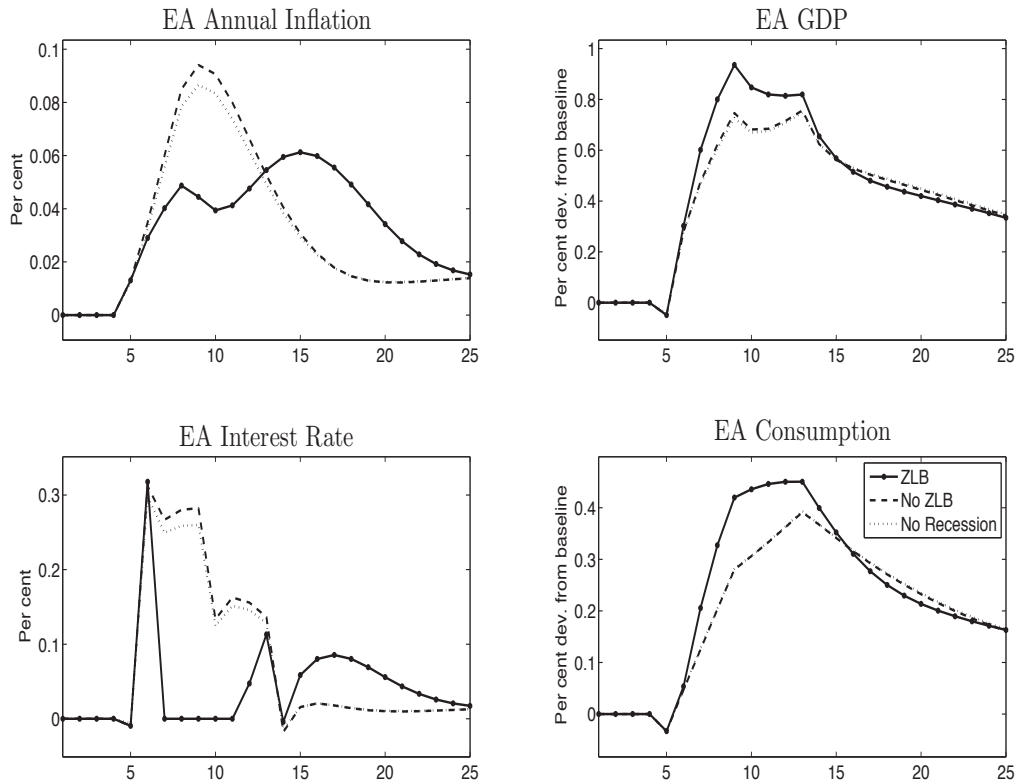
The fiscal packages are simulated assuming that the economy is hit by the global recession shock of section 3. As in section 4, the fiscal packages are assumed to be announced four periods into the recession and implemented in the fifth period. The implementation is set to coincide with the entry into the ZLB, a situation similar to that actually faced by governments.<sup>28</sup>

The results of the simulations for the euro area are shown in Figure 7. The path for each variable is the difference relative to the case in which there is recession but no fiscal reaction. As seen in the figure, the size of the foreseen packages is not sufficient to significantly change the profile of the euro area interest rate. In fact, the inflationary impact of the packages in the euro area would be relatively small, so that the ZLB would not be overcome. Nevertheless, the packages reduce the magnitude of the recession, leading to a smaller decline of consumption and real GDP. In the case of the US, however, the announced fiscal packages would be sufficiently powerful to keep the interest rate away from the ZLB almost all the time (see Figure 8). This is due to the large size of the package being implemented, which has a significant impact on GDP growth and inflation. Also noteworthy in all simulations is the amplification role of the ZLB for the fiscal shocks which always have a stronger effect on GDP and consumption in the ZLB case

<sup>28</sup>A corollary of the previous section, on fiscal multipliers in the ZLB, is that the starting cyclical position of the economies is of second-order importance. We have thus retained the recession in the previous sections, which increases the comparability of all the exercises reported in the text.



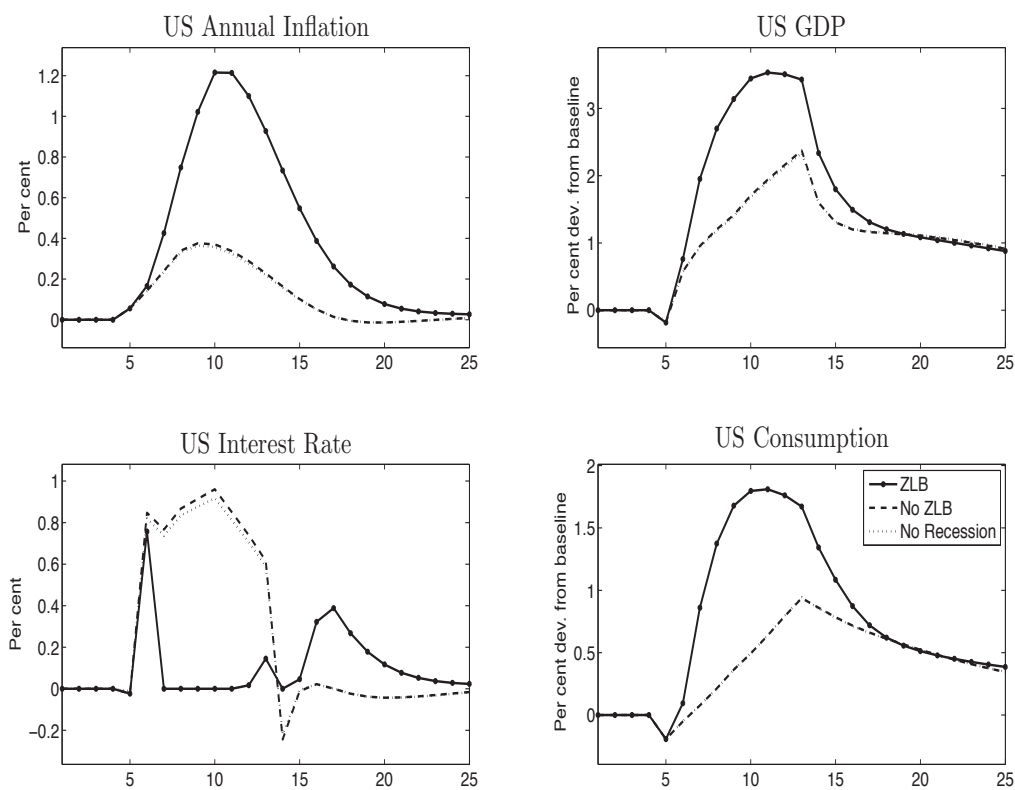
Figure 7: The impact of the planned fiscal packages: euro area



than in the no-ZLB or no-recession cases.

Overall, the planned fiscal packages would help in reducing the magnitude of our benchmark recession, including a sizeable boost during the ZLB period. The finding is particularly relevant for the US, where both the size of the fiscal programme and the longer period spent in the ZLB support activity. It should be stressed that the simulations disregard potential side effects of the packages on the risk premium of government debt, which would reduce their impact.

Figure 8: The impact of the planned fiscal packages: US



## 7 Conclusion

This paper has investigated the use of fiscal policy instruments to overcome a zero lower bound (ZLB) situation, using a large scale DSGE model. The model (EAGLE) includes 4 blocs for Germany, the rest of the euro area, the US and the rest of the world. The ZLB situation is reached in the model by assuming an exogenous huge global recession. The fiscal response is always assumed to include temporary measures only. The results are in line with the literature in that we generally find fiscal policy stimulus measures to be effective in reducing the duration of a ZLB episode. In addition, the fiscal multipliers are enhanced during the ZLB period, due to the inability of monetary policy to react.

Of the several fiscal instruments that can be used, government consumption seems to be among the most powerful instrument for overcoming the ZLB in EAGLE. However, both in the euro area and the US, an increase in Government consumption amplifies the decline in consumption generated by the recessionary shocks. In this respect, the use of a VAT tax leads to a smaller loss in consumption while also significantly reducing the duration of the ZLB. Transfers are most affected by the extent of Ricardian behaviour in the economy, from mildly effective (when most consumers are non-Ricardian) to totally ineffective. This policy should be considered most risky, unless there is a clear view about consumer behaviour. Finally, the use of an income tax would prolong the ZLB situation, which would be undesirable, even though it would lead to a stronger exit from the recession.

It should be noted that even though the results suggest that fiscal policy may be useful in alleviating the negative consequences of a major recession leading to the ZLB, other considerations suggest caution in using fiscal policy stimulus in the context of major recessions. To start with, we assume that all the fiscal measures are temporary and credible. This implies, in particular, that fiscal authorities announce a return to pre-recession levels of debt, to be achieved by future fiscal consolidation. Agents in EAGLE believe the announcement and expect an episode of future tightening, which actually increases the impact of the immediate fiscal expansion.

A loss of credibility brought about by rising public indebtedness would lead to higher sovereign

bond risk premia which could seriously hamper or even eliminate the effectiveness of fiscal policy as a tool to overcome the ZLB. In addition, as fiscal multipliers rise significantly in a ZLB situation, which, according to our results, appears to be particularly the case in the US, there is an increased risk of temporary fiscal policy measures resulting in more stimulus than is needed, especially if policymakers rely on traditional fiscal multipliers. This risk seems particularly high for inflation in the US. Thus, the risks of the economy falling into a deflationary spiral need to be carefully traded off with the risks of overstimulating the economy (in particular inflation) and longer-term issues related to the sustainability of public finances.

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