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Exit Strategies

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Non-Technical Summary

In all industrial countries, public sector deficits have expanded sharply since the second half of 2008 because of a combined effect of automatic stabilizers, on both the expenditure and revenue sides, and discretionary measures to support the financial, corporate and household sectors.

While the fiscal problem is paramount, the question of how to revert to the anti-crisis measures and to return to a normal policy setting (the "exit strategy" problem) is not limited to budgets. Central banks have pegged interest rates close to zero virtually everywhere since late 2008, and a number of enhanced monetary and credit support programs were enacted. Exiting the monetary expansion entails a dilemma. On the one hand, delaying the exit may be helpful for the recovery and also for fiscal sustainability by reducing the interest burden. On the other hand, the exceptionally strong and protracted monetary expansion may encourage risk-taking in the financial sector as demonstrated by recent evidence.

We study alternative scenarios for exiting the post-crisis fiscal and monetary accommodation using a macro model in which banks choose their capital structure and are subject to runs. Under a Taylor rule, the post-crisis interest rate hits the zero lower bound (ZLB) and remains there for several years. In that condition, pre-announced and fast fiscal consolidations – based on output and inflation performance and bank stability – dominate alternative strategies incorporating various degrees of gradualism and surprise. We also examine an alternative monetary strategy in which the interest rate does not reach the ZLB. In this scenario, the benefits from fiscal consolidation persist, but are more nuanced.

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Exit Strategies*

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Abstract

We study alternative scenarios for exiting the post-crisis fiscal and monetary accommodation using a macromodel where banks choose their capital structure and are subject to runs. Under a Taylor rule, the post-crisis interest rate hits the zero lower bound (ZLB) and remains there for several years. In that condition, pre-announced and fast fiscal consolidations dominate – based on output and inflation performance and bank stability – alternative strategies incorporating various degrees of gradualism and surprise. We also examine an alternative monetary strategy in which the interest rate does not reach the ZLB; the benefits from fiscal consolidation persist, but are more nuanced.

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Keywords: exit strategies, debt consolidation, fiscal policy, fiscal multipliers, monetary policy, bank runs

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1 Introduction

The more experience we gain with this crisis and its aftershocks, the clearer it becomes that reversing the policies put in place in response to it and neutralizing their side effects will confront policy makers with more serious and enduring problems than the crisis itself. Fiscal policy is at the center of this challenge. In all industrial countries, public sector deficits expanded sharply since the second half of 2008 for the combined effect of automatic stabilizers, on both the expenditure and revenue sides, and discretionary measures to support the financial, corporate and household sectors. The extent and nature of the official support varied across countries, but the overall effect was impressive by all standards. Budget deficits increased by about 5 percent of GDP between 2008 and 2009 in both the US and the euro area. Long run simulations by the IMF (see e.g. Cottarelli and Viñals [18]) show that the debt dynamics will, under favorable circumstances, lead to increases in public debt ratios in the order of 40 percent or more in the next 6 to 8 years in the advanced countries. An orderly exit from such imbalances will require sustained consolidation effort for decades, and in the meantime public finances will remain highly vulnerable to further shocks.

While the fiscal problem is paramount, the question of how to revert the anti-crisis measures and return to a normal policy setting (the "exit strategy" problem) is not limited to budgets. Central banks pegged interest rates close to zero virtually everywhere in late 2008, and a number of enhanced monetary and credit support programs were enacted. Exiting the monetary expansion entails a dilemma. On the one hand, delaying the exit may help the recovery and also fiscal sustainability, by reducing the interest burden. On the other, the exceptionally strong and protracted monetary expansion may encourage risk-taking in the financial sector, as demonstrated by recent evidence (see a brief survey and the macro evidence in Angeloni, Faia and Lo Duca [5]). In the long run, a protracted monetary expansion can become an obstacle to the restoration of balanced financial conditions. Moreover, a dilemma arises from the interaction between bank fragility and public finances. Publicly funded bank support programs need to be reversed, lest overburdening public finances and fueling moral hazard. Second, financial sector reforms, underway in all major countries under the leadership of the G20, include as a central prescription a strengthening of bank capital. On both fronts, action is needed for structural reasons, but excessive front-loading risks delaying the recovery.

In analyzing exit strategies several interconnected factors must be taken into consideration. The fiscal adjustment is heavily influenced by the timing and modality of monetary exit, but the reverse is also true, because fiscal consolidation will affect a number of macro-variables that are

in the informational radar screen of central bankers. These multiple interconnections suggest that the exit strategies should not be examined one at a time, but in combination. A comprehensive analytical framework is needed to approach the problem.

For this purpose we use an adapted version of the model by Angeloni and Faia [4], henceforth AF. AF integrate a risky banking sector, following the relationship lender theory spelled out in Diamond and Rajan (henceforth DR) [22], [23] in a conventional macro framework, and analyse the transmission of monetary and other shocks in an economy with fragile banks as well as the effects of different types of dynamic bank capital buffers. Banks determine their leverage and balance sheet risk endogenously, influenced by several factors including the stance of monetary policy. Other things equal, a protracted monetary expansion increases bank leverage and risk. Bank risk in our model is measured by the probability that the bank experiences a run on its short term uninsured liabilities[1], an event that triggers costly liquidation of investment projects. In this respect we follow the notion of "fundamental bank run"[2] in which the collective action is triggered by news of a shock on the investment returns (the fundamentals). Banks in this context raise liquidity through short demandable uninsured liabilities ("deposits") that, due to a service constraint, do not require the payment of rents (as opposed to bank capital): when the interest rate is low and in order to economize on rents, banks tend to increase the share of demandable deposits, thereby exposing themselves to run and increasing bank riskiness[3]. Hence, in addition to the usual channels of monetary policy, there is also a "risk-taking" channel, affecting macroeconomic outcomes via the extent of risk present in the bank balance sheets.

We extend the AF model in three directions. First, we add a fiscal sector, including policy functions for public spending, labour and consumption taxes, as well as debt accumulation. This detail is needed to study alternative mixes of fiscal consolidation strategies and to account for debt dynamics. Second, we augment the bank capital accumulation process by adding in a further component, given by publicly funded bank recapitalization. We call this "unconventional" fiscal policy, to distinguish it from the "conventional" one consisting in (different combinations of) public spending increases and tax reductions. This adds realism to the model in the post-crisis phase, where both types of fiscal interventions were put in place in virtually all industrialized countries. Thirdly, we apply newly developed methods to analyse and compare complex sequences of shocks

[1] In the years prior to the 2007 crisis banks on both sides of the Atlantic increasingly financed themselves by rolling-over short term uninsured liabilities, such as asset backed securities and repos. In spite of their (apparent) high degrees of seniority and triple A rating, the ensuing crisis resulted in a dry up or a run on those assets. See Gorton and Metrick [27].

[2] The alternative notion is that of a self-fulfilling bank run as in Diamond and Dybvig [21]. For early formulation of the notion of fundamental bank run see Gorton [26]. Diamond and Rajan [22] and Allen and Gale [1].

[3] Notice that runs triggered by fundamentals arise since they play the role of discipline devices for the bank.

and policy responses, with different timing and informational assumptions. We start from a crisis scenario triggered by a combination of adverse shocks, which increases bank risks and generates a recession. We examine two alternative monetary policy responses, one consisting in hitting the zero lower bound (ZLB) and "exiting" it endogenously, following a standard Taylor rule, the second in smoothing the downward interest rate movement so as to avoid hitting the ZLB. The fiscal exit is modelled as a change in the fiscal rules (conventional and/or unconventional), in the direction of a faster consolidation of public debt. We examine a variety of such rules that differ for the speed of debt consolidation, the information provided to economic agents, the composition of fiscal adjustment, etc. This approach permits us to pose questions that are relevant for many current discussions on exit strategies, such as gradualism versus preemptive action, sequencing and delay (who should exit first, fiscal or monetary policy? What is the cost or benefit from delaying?) and communication policy (should exit strategies be pre-announced)?

Our main conclusions can be summarized as follows. First, exiting the post-crisis fiscal policy stance is beneficial; almost any fiscal consolidation strategy leads to an improvement in terms of our evaluation criteria (intertemporal changes in output, inflation, bank risk and agents' welfare) relative to the status quo, i.e., the indefinite continuation of the post-crisis accommodative fiscal policy course. The gain is greater in the medium-long term; in the short run (first 20 quarters) the results are mixed. Not all exit strategies are alike, though. Proactive fiscal strategies, geared to an ambitious debt consolidation target, dominate gradual ones. Announced fiscal consolidation plans tend to dominate – with some qualifications – surprise ones. The composition of fiscal policy matters; spending-based fiscal strategies are superior to tax-based ones – less so, however, when the interest rates hits the ZLB. The results concerning sequencing are more nuanced, though in most cases strategies in which fiscal policy abandons the accommodative stance before monetary policy tend to dominate, especially if the fiscal strategy is aggressive and pre-announced. These results are robust, with some qualifications, to the two monetary policy we consider: the conventional Taylor rule, that implies that short term rates quickly hit the zero-lower-bound (ZLB), as happened in many industrialized countries after the crisis, and one with smoother interest rate response, where the ZLB is avoided, a case we regard as more akin to the behavior of the ECB.

The rest of the paper is organized as follows. Section 2 reviews the related literature and highlights the areas where this paper contributes. Section 3 describes the model. Section 4 describes the calibration of the model, the policy regimes and the construction of the exit strategies. Section 5 describes our baseline path, which includes two elements: the initial shocks and the immediate policy responses. With the model we roughly mimic the path of the main macro-variables in the first two years after the financial crisis in the euro area and the US (where the macro responses were

rather similar). The next step, in section 6, is to analyse a number of alternative strategies of exit from fiscal and monetary accommodation (paths of the main macro variables following alternative combination of changes in the existing fiscal and, to a more limited extent, monetary rules), and compare their performance against the baseline. To do this we rely on impulse response functions and quantitative metrics. Next, in section 7 we examine the robustness of these results to the monetary policy strategy that avoids the ZLB. Finally, section 8 concludes.

2 Links to the literature

In the aftermath of the crisis most of the literature on fiscal and monetary policy focused on analyzing how effective unconventional monetary and fiscal policy could be in managing the crisis. All countries let fiscal automatic stabilizers play fully, and most also enacted discretionary stimulus packages. Monetary policy adopted a proactive expansionary stance, particularly in the US, where, since the aggravation of the crisis in late 2008, the reference interest rate has remained close to zero.

Following Romer and Bernstein [33], a number of papers have revisited the question of how large fiscal multipliers are, in various cyclical and policy contexts. We refer to this literature and also compute fiscal multipliers in the context of our model, hence contributing to that literature as well, but only to the extent needed for our purpose, namely to evaluate alternative strategies for exiting the post-crisis fiscal accommodation (in terms of timing and composition of fiscal consolidation).

Regarding monetary policy, in the US much of the discussion has focused on how the Federal Reserve should enact unconventional monetary measures to deal with the crisis and how they should subsequently be phased out. We do not focus on short term crisis management and do not consider unconventional monetary tools, but we focus on how conventional monetary policy can, in combination with fiscal policy, ensure the best combination of macro performance and bank stability over the medium-long term.

Our paper is also related to the literature on policy regimes. Davig and Leeper [19] estimate Markov-switching policy rules for the United States and find that monetary and fiscal policies fluctuate between active and passive behavior (active monetary policy meaning that the nominal interest rate is highly reactive to inflation, while active fiscal policy means that the primary surplus does not respond strongly enough to government debt to stabilize it), while Davig, Leeper and Walker [20] apply the same framework to study the consequences of alternative means to resolve the "unfunded liabilities"problem. Although promising for our questions as well, the Markov switching approach presents technical obstacles when applied to a complex model like ours. Hence we prefer,

at this stage, to stick to a simpler deterministic approach that we explain in the Web Appendix.

In terms of monetary policy transmission, our model features both a bank balance sheet channel and a risk taking channel[4]. A banks' balance sheet channel coupled with fire sales has been introduced in many recent models through collateral constraints on bank capital or short term liabilities. As bank capital or short term lending are linked to future values of banks' assets via the collateral constraint, falls in asset prices trigger downward spirals in lending and assets' values. In our model bank capital is chosen endogenously as an optimal fraction of the total value of investment: changes in the value of investment, triggered by changes in asset prices, also affect the value of bank capital and bank liquidity. Earlier papers merging macro and banking typically did not contain an endogenously determined risk-taking behavior by banks, nor did they allow for bank runs or defaults as a result of such behavior. This makes the AF model well-suited for analyzing exit strategies: in our model low monetary policy rates, on the one side, increase banks' balance sheet values by fueling asset prices in the short run; on the other side, they tempt intermediaries toward excessive leverage, which in turn fuel banks' risk. On reverse this implies that the exit from monetary accommodation involves two contrasting effects, one, contractionary, via the traditional balance sheet channel and another, expansionary, due to the mitigation of bank risks via the risk taking channel. Importantly in our model bank's risk bears resource costs due to the potential early project liquidation ensuing banks' runs. This interaction is useful to analyse a dilemma facing central banks in this juncture, namely, how to balance the benefits of delaying the exit from expansionary monetary policy with the risks of igniting moral hazard and risk in the financial system. Moreover, our banking model allows us to measure the effect of alternative policies on macroeconomic variables and on bank risk, hence including all relevant elements in this trade-off.

An additional remark is in order concerning the type of bank runs considered in our model. Runs in our model fall within the category of fundamental or information based runs. We focus on those for various reasons. First, the finance literature has elaborated on the correct notion of bank runs moving from the pioneering contribution of Diamond and Dybvig [21], in which runs can occur in healthy banks solely because of liquidity shocks on depositors, to the more general case in which runs occur when investors receive bad news on asset returns (see Diamond and Rajan [22] and Allen and Gale [1]). Note that bank risk can only be measured in this second type of runs, since liquidity based runs occur either with probability one or zero. This evolution was dictated

[4]In Angeloni and Faia [4] it is shown that the behavior of banking variables is generally aligned to that in the data, generating among other things pro-cyclical bank capital and cyclical properties of bank risks which match well the data equivalent.

also by the vast empirical literature, starting with Calomiris and Mason [14], providing evidence on the link between bank runs (and/or banks' crises) and fundamentals. The 2007-2008 crisis was actually characterized by a liquidity dry up in bank funding triggered precisely by news of negative shocks on the returns of certain banks' asset. As explained earlier the possibility of bank runs is linked to the presence of demandable uninsured funding instruments (we call them deposits for expositional simplicity), held by non-bank regular investors or by other banks through interbank linkages. In this second case the same type of runs or liquidity dry ups occur in the interbank market: formally the triggers of those runs remain the same (see also Allen and Gale [2]).

The 2007-2008 financial crisis was complex, many channels played a role in the propagation of risk and instability. Weaknesses materialized in the banking sector due to excessive leverage and recourse to short term funding (repos and other securitized instruments).[5] This made the banking system fragile and prone to runs – not on classical deposits, but on on ABS, repos, commercial paper and the like (namely asset created by securitization). Our model, embodying an endogenous mechanism leading to excessive leverage and risk and a potential endogenous run on the bank that generates loss of shareholder/depositor value as well as social costs, contains the above mentioned elements. Several other elements played a role as trigger of the crisis as well as in the diffusion of risk. First, in the US, the shock was given by a collapse in house prices and an increase in mortgage defaults. In our model we do not include housing investment specifically, but we include a shock that hits directly the bank's asset side. Bank losses have been propagated through three main channels. First, through bank runs that by forcing early liquidation of projects' investment produced output losses. Our model contains this channel. Second, losses have been transmitted through fire sales: as banks had to meet regulatory requirements they sold assets in their portfolio in response to the negative shocks on the value of their asset (see Cifuentes, Ferrucci, and Shin [15]): the ensuing fall in asset prices produced losses on banks' balance sheets. Our model only partly captures this second channel: as negative shocks are transmitted to the system the price of investment falls in our model through general equilibrium effects; the fall in asset prices produces falls in the banks' balance sheet values as explained above. Third, banks' losses have been propagated through direct network interconnections both through borrowing cross-exposure in the interbank market and through insurance contracts traded in the CDS market (see Bluhm, Faia and Krahnen [11] and Aldasoro and Angeloni [6]), an element we neglect here.

[5]This interpretation is now virtually consensual, see papers by Gorton and Metrick [27], Morris and Shin [31], and most recently Hanson, Kashyap and Stein [28]. Interbank linkages were a facilitators of the crisis.

3 The Model

Our starting point is the model developed in AF [4], who introduce banks following DR [22], [23] into a conventional DSGE model with nominal rigidities. To this we add a fiscal sector which sets government expenditure following an operational rule that responds to past spending and government debt. Government spending is financed through a mix of labour and consumption taxes and government debt. Monetary policy follows a Taylor rule, with interest rate smoothing, subject to a zero lower bound (ZLB) constraint.

There are four sectors in this economy: households, banks, goods producers and capital producers. Within households there are workers/consumers, holders of financial assets (deposits and government bonds), owners of the production sector, bank capitalists and bank managers. Financial intermediaries fund projects by raising deposits (which in our terminology coincide with uninsured short-term liabilities, as already explained) and bank capital. Projects are subject to an idiosyncratic shock, which generates the possibility of bank runs. As in DR [22], [23] the bank capital structure is determined by bank managers, who act on behalf of outside investors (depositors and bank capitalists combined) by maximizing their overall return[6]. Once the project's uncertain outcome is realized, bank capitalists claim the residual after depositors are paid out. If the return on bank assets is low and the bank is not able to pay depositors in full there is a run on the bank, in which case the bank capital holders get zero while depositors get the market value of the liquidated loan[7]. We assume that the production sector includes monopolistic firms that face quadratic adjustment costs on prices: such assumption allows to generate non-neutral effects of monetary policy on demand.

3.1 Households

There is a continuum of identical households who consume, save and work. Households (including both workers/depositors and bank capitalists) save by lending funds to the financial intermediaries, in the form of deposits and bank capital, and by purchasing government bonds. To allow aggregation within a representative agent framework we assume that in every period a fraction γ of household members are bank capitalists and a fraction $(1-\gamma)$ are workers/depositors. Hence households also own financial intermediaries. Bank capitalists remain engaged in their business activity next

[6] Diamond and Rajan [23] design a bargaining process between the outside financiers and the manager, so that the latter gets a specifically defined share of the total return: in this way the manager has the sole interest of maximizing total returns.

[7] Full insurance of bank liabilities is ruled out by optimality: under full insurance moral hazard and risk taking incentives are unbounded. Such an assumption also adds realism to the financial contract since in all countries insured deposits are a small fraction of total bank liabilities.

period with a probability θ, which is independent of history. This finite survival scheme is needed to avoid that bank capitalists accumulate enough wealth to ease the liquidity constraint. According to this structure a fraction $(1-\theta)$ of bank capitalists exit in every period. A corresponding fraction of workers become bank capitalists every period, so that the share of bank capitalists, γ, remains constant over time. Workers earn wages and return them to the household; similarly bank capitalists return their earnings to the household. However, the earnings of bank capitalists are not used for consumption but are given to the new bank capitalists and reinvested as bank capital (see capital accumulation equation 17 below). Consumption and investment decisions are made by the household, pooling all available resources. Household members can either work in the production sector or in the financial sector[8].

Households maximizes the following discounted sum of utilities

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\sigma} (C_t^{(i)} - \xi C_{t-1})^{1-\sigma} + \nu \log(1 - N_t^{(i)}) \right] \tag{1}$$

where $C_t^{(i)}$ denotes individual consumption, C_{t-1} denotes aggregate past consumption, and $N_t^{(i)}$ denotes individual labour hours. The introduction of habit persistence in consumption through the dependence of the utility from past aggregate consumption smooths out fluctuations in consumption, thereby rendering its path empirically more plausible. Households save and invest in government bonds, B_t, bank deposits, D_t, and bank capital. Deposits pay a gross nominal return one period later; due to the possibility of bank run, this return is subject to a time-varying risk premium δ_t equivalent to the expected loss for the depositor. Finally, households are also the owners of the monopolistic competitive sector, hence they receive real profits for an amount, Θ_t. The budget constraint, in aggregate terms, reads as follows:

$$(1+\tau_t^c)C_t + \frac{B_t}{P_t} + \frac{D_t}{P_t} = (1-\tau_t^n)\frac{W_t}{P_t}N_t + R_{f,t-1}\frac{B_{t-1}}{P_t} + (1-\delta_{t-1})R_{t-1}\frac{D_{t-1}}{P_t} + \tau_t + \Theta_t + \Xi_t$$

where R_t is the risky rate on deposits and $R_{f,t}$ is the risk-free rate.[9] τ_t^c and τ_t^n are taxes on consumption purchases and labour income, respectively. τ_t denotes a lump-sum transfer. Finally Ξ_t is the time-varying fee received by bank managers, defined below in section 3.2.

[8] A small fraction of workers is employed in the financial sector as bank managers. Bank managers have an inelastic labour supply for which they receive a time-varying fee, derived below in the paper.

[9] The risk premium is given by the expected loss on deposits $\delta_t = br_t \cdot (R_t - R_t \mid_{run})$, where $R_t \mid_{run}$ is the gross rate of return on deposits conditional on the bank being run and br_t is bank riskiness defined below in section 3.2. Note that we assume away risk premia on government bonds. This is not a harmless assumption, because an ambitious fiscal consolidations could reduce sovereign risk spreads hence dampening the accumulation of debt and elevating the long-term benefits of fiscal consolidation further. In this way our results tend to underestimate the effect of ambitious fiscal exit strategies. We leave the inclusion of endogenous bond spreads to future work.

The following optimality conditions (alongside with a No-Ponzi conditions) hold after aggregation:

$$\lambda_t^C = (C_t - \xi C_{t-1})^{-\sigma} \frac{1}{1+\tau_t^c} \tag{2}$$

$$\lambda_t^C = \beta E_t \left\{ \lambda_{t+1}^C \frac{R_t(1-\delta_t)}{\pi_{t+1}} \right\} \tag{3}$$

$$\lambda_t^C = \beta E_t \left\{ \lambda_{t+1}^C \frac{R_{f,t}}{\pi_{t+1}} \right\} \tag{4}$$

$$\frac{W_t}{P_t} = \nu \left[(1-N_t)\lambda_t^C (1-\tau_t^n) \right]^{-1} \tag{5}$$

where $\pi_{t+1} = \frac{P_{t+1}}{P_t}$. Equation 2 gives the marginal rate of substitution. Equation 3 is the optimal choice for deposits. Equation 4 gives the optimality condition on bonds. Finally equation 5 gives the optimal choice of labour supply. Optimality also requires to satisfy the no-Ponzi game condition on wealth.

3.2 Banks

There is in the economy a large number (L_t) of un-correlated investment projects. The project lasts two periods and requires an initial investment. Each project's size is normalized to unity (think of one machine) and its price is Q_t. The projects require funds, that are provided by the bank; each bank invests in one project[10]. Banks have no internal funds but receive finance from two classes of agents: demand deposit holders and bank capitalists. The term bank here refers to the organizational structure in which external funds are provided by depositors and bank capitalists (whom we also define as outside investors) and which is run by a manager who has the non-sellable knowledge of a relationship lender.

Total bank loans (equal to the number of projects multiplied by their unit price) are equal to the sum of deposits (D_t) and bank capital (K_t^B). The aggregate bank balance sheet is:

$$Q_t L_t = D_t + K_t^B \tag{6}$$

The capital structure (deposit share, equal to one minus the capital share) is determined by bank manager on behalf of the outside investors. The manager's task is to find the capital structure that maximizes the combined expected return of depositors and capitalists, in exchange for a fee. Individual depositors are served sequentially and fully as they come to the bank for withdrawal; bank

[10]We thus assume away perfect diversification of the bank asset size. Ours is a model of relationship lending: each bank finances one project and acquires special information on it. In presence of relationship lending and inside information about the characteristics of the loan, what the bank does is to establish a close relation with one or few firms (projects in our model) and extract information from monitoring.

capitalists instead are rewarded pro-quota after all depositors are served. This payoff mechanism exposes the bank to runs, that occur when the return from the project is insufficient to reimburse all depositors; as soon as they realize that the payoff is insufficient, they run the bank and force the liquidation of the project. The timing is as follows. At time t, the manager of bank k decides the optimal capital structure, expressed by the ratio of deposits to total loans, $d_{k,t} = \frac{D_{k,t}}{Q_{k,t}L_{k,t}}$, collects the funds, lends, and then the project is undertaken. At time $t+1$, the project's outcome is known and payments to all stakeholders (depositors, bank capitalists, the manager) are made, as discussed below. A new round of projects starts. Note that, since we are using a notion of "fundamental bank run" – that is, the run occurs if the realization of the project financed by the bank is too low to enable the bank to repay depositors – the timing of the model can be simplified[11].

Generalizing DR [22], [23], we assume that the return of each project for the bank is equal to an expected value, $R_{A,t}$, plus a random shock, for simplicity assumed to have a uniform density with dispersion h (the assumption yields a convenient closed form solution but is not essential; see AF [4] for the case of logistic and normal distributions). Therefore, the project j outcome is $R_{A,t} + x_{j,t}$, where $x_{j,t}$ spans across the interval $[-h; h]$ with probability $\frac{1}{2h}$. We assume h to be constant across projects.

Given our assumption of identical projects and banks, for notational convenience from now on we can omit project and bank subscripts. Each project is financed by one bank. Our bank is a relationship lender: when it lends, its bank managers acquire a specialized non-sellable knowledge of the characteristics of the project. This knowledge determines an advantage in extracting value from it before the project is concluded, relative to other agents. Let the ratio of the value for the outside investors (liquidation value) to the value for the bank be $0 < \lambda < 1$. Even if the project is liquidated, a run is assumed to entail a loss of resources; if the run occurs, the recovery rate is reduced by a factor $1 - c$, where $1 > c \geq 0$.

Suppose the ex-post realization of x_t is negative and consider how the payoffs of the three players are distributed depending on the ex-ante determined value of the deposit ratio d_t and the deposit rate R_t. There are three cases.

Case A: Run for sure. The outcome of the project is too low to pay depositors. This happens if $R_{A,t} + x_t < R_t d_t$. Payoffs are distributed as follows. Capitalists only get a payoff if all depositors are served, so they get zero in this case. Depositors alone (without bank) would get only a fraction $\lambda(1-c)(R_{A,t}+x_t)$ of the project's outcome; the remainder $(1-\lambda)(1-c)(R_{A,t}+x_t)$ is shared between

[11] Contrary to the case of self-fulfilling runs where depositors are subject to different liquidity shocks, in models with fundamental bank runs all depositors uniformly perceive the bad signal of the investment returns. The run occurs in the moment in which the information on the return becomes public.

depositors and the bank manager depending on their relative bargaining power. We assume this extra return is split in half (other assumptions are possible without qualitative change in the results). Therefore, depositors end up with:

$$\frac{(1+\lambda)(1-c)(R_{A,t}+x_t)}{2}$$

and the bank manager with

$$\frac{(1-\lambda)(1-c)(R_{A,t}+x_t)}{2} \tag{7}$$

Case B: Run only without the bank. The project outcome is high enough to allow depositors to be served if the project's value is extracted by the bank, but not otherwise. This happens if $\lambda(R_{A,t}+x_t) < R_t d_t \leq (R_{A,t}+x_t)$. In this case, the capitalists alone cannot avoid the run, but with the intervention of the relationship lender they can. Hence the run does not occur, depositors are paid in full, $R_t d_t$, and the remainder is split in half between the bank managers and the capitalists, each getting $\frac{R_{A,t}+x_t-R_t d_t}{2}$. Total payment to outsiders is $\frac{R_{A,t}+x_t+R_t d_t}{2}$.

Case C: No run for sure. The project's outcome is high enough to allow all depositors to be served, with or without the relationship lender's participation. This happens if $R_t d_t \leq \lambda(R_{A,t}+x_t)$. Depositors get $R_t d_t$. However, unlike in the previous case, now the capitalists have a higher bargaining power because they could decide to liquidate the project alone and pay the depositors in full, getting $\lambda(R_{A,t}+x_t) - R_t d_t$; this is thus a lower threshold for them. The bank capitalist can extract $(R_{A,t}+x_t) - R_t d_t$, and again we assume that the capitalist and the bank manager split this extra return in half. Therefore, the bank manager gets:

$$\frac{[(R_{A,t}+x_t) - R_t d_t] - [\lambda(R_{A,t}+x_t) - R_t d_t]}{2} = \frac{(1-\lambda)(R_{A,t}+x_t)}{2}$$

This is less than what the capitalist gets. Total payment to outsiders in this case is:

$$\frac{(1+\lambda)(R_{A,t}+x_t)}{2}$$

We can now write the expected value of total payments to outsiders as follows:

$$\frac{1}{2h}\int_{-h}^{R_t d_t - R_{A,t}} \frac{(1+\lambda)(1-c)(R_{A,t}+x_t)}{2} dx_t + \frac{1}{2h}\int_{R_t d_t - R_{A,t}}^{\frac{R_t d_t}{\lambda} - R_{A,t}} \frac{(R_{A,t}+x_t)+R_t d_t}{2} dx_t \tag{8}$$
$$+ \frac{1}{2h}\int_{\frac{R_t d_t}{\lambda} - R_{A,t}}^{h} \frac{(1+\lambda)(R_{A,t}+x_t)}{2} dx_t$$

The three terms express the payoffs to outsiders in the three cases described above, in order. The manager's problem is to maximize expected total payments to outsiders by choosing the suitable value of d_t. The solution yields the following solution for the level of deposits for each unit of loans:

$$d_t = \frac{1}{R_t} \frac{R_{A,t} + h}{2 - \lambda + c(1+\lambda)}. \tag{9}$$

Since the second derivative is negative, this is the optimal value of d_t. For analytical details characterizing the solution the reader is referred to the paper by AF [4]. There it is also shown that a similar relation between d_t and its determinants holds for a variety of assumptions concerning the probability distribution of the underlying shock.

We measure bank riskiness by the probability of a run occurring. This can be written as:

$$br_t = \frac{1}{2h} \int_{-h}^{R_t d_t - R_{A,t}} dx_t = \frac{1}{2} \left(1 - \frac{R_{A,t} - R_t d_t}{h} \right) \tag{10}$$

The manager's fee is given by an expression similar to equation 8, replacing the appropriate expressions derived above for the payoff of the bank manager in the different cases:

$$\begin{aligned} \Xi_t = \frac{1}{2h} \int_{-h}^{R_t d_t - R_{A,t}} \frac{(1-\lambda)(1-c)(R_{A,t} + x_t)}{2} dx_t + \frac{1}{2h} \int_{R_t d_t - R_{A,t}}^{\frac{R_t d_t}{\lambda} - R_{A,t}} \frac{R_{A,t} + x_t - R_t d_t}{2} dx_t \\ + \frac{1}{2h} \int_{\frac{R_t d_t}{\lambda} - R_{A,t}}^{h} \frac{(1-\lambda)(R_{A,t} + x_t)}{2} dx_t \end{aligned} \tag{11}$$

Accumulation of bank capital and bank recapitalization

In the aggregate, the amount invested in every period is $Q_t L_t$. The total amount of deposits in the economy is

$$D_t = \frac{Q_t L_t}{R_t} \frac{R_{A,t} + h}{2 - \lambda + c(1+\lambda)} \tag{12}$$

and the bank's optimal capital is:

$$K_t^B = \left(1 - \frac{1}{R_t} \frac{R_{A,t} + h}{2 - \lambda + c(1+\lambda)} \right) Q_t L_t \tag{13}$$

Projects are financed by the intermediary for an amount:

$$Q_t L_t = Q_t K_t \tag{14}$$

The above expressions suggest that, following an increase in R_t, the optimal amount of bank capital increases on impact (for given $R_{A,t}$). The effect of other factors in general equilibrium is more complex, depending on several counterbalancing factors affecting $R_{A,t}$ and R_t. Equation 13 is the level of bank capital desired by the bank manager, for any given level of investment, $Q_t L_t$ and interest rate structure (R_t, $R_{A,t}$). As already mentioned we assume that bank capital is provided by the bank capitalist. After remunerating depositors and paying the competitive fee to the bank manager, a return accrues to the bank capitalist, and this is reinvested in the bank as follows:

$$K_t^B = \frac{\theta}{\pi_t}[K_{t-1}^B + R_t^{BK} Q_t K_t] + K_t^{BG} \tag{15}$$

where R_t^{BK} is the unitary return to the capitalist. The parameter θ is our bank survival rate already discussed. In addition, banks receive a transfer that takes the form of bank recapitalization, K_t^{BG}.

The return accruing to bank capitalists in every periods, R_t^{BK}, can be derived as follows:

$$R_t^{BK} = \frac{1}{2h} \int_{R_t d_t - R_{A,t}}^{h} \frac{(R_{A,t} + x) - R_t d_t}{2} dx_t = \frac{(R_{A,t} + h - R_t d_t)^2}{8h} \tag{16}$$

This expression considers only the no-run state, because if a run occurs the capitalist receives no return. Note that since individual returns are linear in the optimal bank capital, aggregation of individual bank capital accumulation is possible. Aggregate bank capital accumulation is obtained by substituting 16 into 15:

$$K_t^B = \frac{\theta}{\pi_t}[K_{t-1}^B + \frac{(R_{A,t} + h - R_t d_t)^2}{8h} Q_t K_t] + K_t^{BG} \tag{17}$$

3.3 Banks' Balance Sheet Channel, Fire Sales and Risk Taking Channel

To guide the interpretation of our later results, some discussion of the transmission channels is in order. In the decision about whether/when to exit, there is a trade-off between the benefits of expansionary policies and their costs. By looking at the real sector of our economy, some of the short run benefits are clear: in a sticky-price model, lowering the interest rate results in expansion of aggregate demand and output. The channels and trade-offs in the banking sector are more complex. On the one side, our banking sector features a banks' balance sheet channel triggered by negative financial shocks. A financial shock, by decreasing the asset price Q_t, reduces bank capital, see equation 13. As in all models featuring a balance sheet channel, the fall in balance sheet value *ceteris paribus* calls for expansionary policies, i.e. lowering interest rate and possibly increasing bank capital using public funds.

Moreover, based on equation 17, also next period capital value is reduced, therefore implying a shrinking in next period lending as from the equation $Q_{t+1}L_{t+1} = D_{t+1} + K^B_{t+1}$. The reduced availability of lending induces a sale of banks' assets. The ensuing fall in investment triggers further falls in next period asset prices and this may produce a progressive negative spiral, akin to a fire sale. This mechanism also calls for expansionary policies, at least until the value of bank capital has been restored.

However, in addition to these linkages our banking sector features also a risk taking channel, given by the fact that low interest rates generate an increase in bank risks. The latter is a source of long run costs of expansionary policies. At low interest rates banks are tempted to increase the share of short term liabilities, therefore increasing leverage and bank riskiness. This can be seen by inspecting equation 9. Even though in the general equilibrium a fall in R_t triggers a fall in $R_{A,t}$, the risk premium, represented by the ratio $\frac{R_{A,t}}{R_t}$, increases, therefore inducing an increase in d_t and an increase in br_t. The occurrence of bank runs is associated with project liquidation: hence an increase in br_t increases the resource costs of project liquidation. Furthermore an increase in the risk premium triggers, in the medium to long run period, a fall in asset prices and investment. In presence of such channel, an expansionary policy might, in the medium to long run, depress investment and output relatively to the case in which the above mentioned channel is absent.

The appropriate timing to exit from expansionary policies results from the balance of the counter-acting forces described above. In the initial periods, the considerations related to the balance sheet channel tend to prevail and expansionary policies deliver better outcomes than no intervention. As the bank risks builds up, its detrimental effects on asset prices tend to downgrade the benefits of low interest rates on the recovery of balance sheet values. Hence, it is appropriate to exit.

3.4 Producers

Each firm i has monopolistic power in the production of its own variety and therefore has leverage in setting the price. In changing prices it faces a quadratic cost equal to $\frac{\vartheta}{2}(\frac{P_t(i)}{P_{t-1}(i)} - 1)^2$, where the parameter ϑ measures the degree of nominal price rigidity. The higher ϑ the more sluggish is the adjustment of nominal prices. In the particular case of $\vartheta = 0$, prices are flexible. Each firm assembles labour (supplied by the workers) and (finished) entrepreneurial capital to operate a constant return to scale production function for the variety i of the intermediate good:

$$Y_t(i) = A_t F(N_t(i), \tilde{K}_t(i)) \tag{18}$$

Each monopolistic firm chooses a sequence $\{\tilde{K}_t(i), L_t(i), P_t(i)\}$, taking nominal wage rates W_t and the rental rate of capital Z_t, as given, in order to maximize expected discounted nominal profits:

$$E_0\{\sum_{t=0}^{\infty}\Lambda_{0,t}[P_t(i)Y_t(i) - (W_tN_t(i) + Z_t\tilde{K}_t(i)) - \frac{\vartheta}{2}\left[\frac{P_t(i)}{P_{t-1}(i)} - 1\right]^2 P_t]\} \tag{19}$$

subject to the constraint $A_tF_t(\bullet) \leq Y_t(i) = (\frac{P_t(i)}{P_t})^{-\varepsilon}Y_t$, namely the optimal demand for each variety. The parameter ε represents the elasticity of individual varieties (aggregated according to the usual Dixit-Stiglitz aggregator), while $\Lambda_{0,t}$ is the households' stochastic discount factor.

Let's denote by $\{mc_t\}_{t=0}^{\infty}$ the sequence of Lagrange multipliers on the above demand constraint. The following first order conditions for profit maximization hold (after aggregation):

$$\frac{W_t}{P_t} = mc_tA_tF_{N,t} \tag{20}$$

$$\frac{Z_t}{P_t} = mc_tA_tF_{\tilde{K},t} \tag{21}$$

$$\lambda_t^C(\pi_t - 1)\pi_t = \beta E_t\{\lambda_{t+1}^C(\pi_{t+1} - 1)\pi_{t+1}\} + \lambda_t^C A_tF_t(\bullet)\frac{\varepsilon}{\vartheta}(mc_t - \frac{\varepsilon - 1}{\varepsilon}) \tag{22}$$

The latter equation is a non-linear forward looking New-Keynesian Phillips curve, in which deviations of the real marginal cost from its desired steady state value are the driving force of inflation.

3.5 Capital sector

A competitive sector of capital producers combines investment (expressed in the same composite as the final good, hence with price P_t) and existing capital stock to produce new capital goods. This activity entails physical adjustment costs. First, capital adjustment costs depend on the change in investment according to $S\left(\frac{I_t}{I_{t-1}}\right)$, where $S(1) = 0$ and $S'(1) = 0$. The capital accumulation equation is then given by:

$$K_{t+1} = K_t(1 - \delta) + \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right]I_t \tag{23}$$

Second, we also consider variable capital utilization. Producers use $\tilde{K}_t = u_tK_t$, which is the effective utilization of the capital stock. The capital utilization rate is determined endogenously. The capital producer maximizes real profits

$$\frac{Z_t}{P_t}u_tK_t - I_t - \Psi(u_t)K_t \tag{24}$$

subject to the capital accumulation equation. Notice that $\Psi(u_t)K_t$ are costs associated with variations in the degree of capital utilization. The first order conditions for profit maximization read

as:

$$\frac{R_{A,t+1}}{\pi_{t+1}} = \frac{\left(\frac{Z_{t+1}}{P_{t+1}} u_{t+1} - \Psi(u_{t+1}) + Q_{t+1}(1-\delta)\right)}{Q_t} \tag{25}$$

$$Q_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] = Q_t S'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right) - \beta Q_{t+1} \frac{\lambda^C_{t+1}}{\lambda^C_t} S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2 + 1 \tag{26}$$

$$\frac{Z_t}{P_t} = \Psi'(u_t) \tag{27}$$

3.6 Equilibrium Conditions, Monetary Policy and the Fiscal Sector

Equilibrium in the final good market requires that the production of the final good equals the sum of private consumption by households, investment, public spending, and the resource costs that originate from the adjustment of prices and capital:

$$Y_t - \Omega_t = C_t + I_t + G_t + \Psi(u_t) K_t + \frac{\vartheta}{2}(\pi_t - 1)^2 \tag{28}$$

where $\Omega_t = c \cdot br_t R_{A,t} Q_t K_t$ is the expected cost of run due to project liquidation. Notice that Ω_t is one of the channels through which risk is contractionary.

Monetary policy is represented by an interest rate reaction function of this form:

$$\ln\left(\frac{R_{f,t}}{R_f}\right) = \max\left\{-\ln R_f, (1-\phi_r)\left[\phi_\pi \ln\left(\frac{\pi_t}{\pi}\right) + \phi_y \ln\left(\frac{Y_t}{Y}\right)\right] + \phi_r \ln\left(\frac{R_{f,t-1}}{R_f}\right)\right\} \tag{29}$$

All variables are deviations from the target or steady state (symbols without time subscript). Note that the monetary policy reaction rule is specified in the risk-free rate $R_{f,t}$[12].

Fiscal policy is also described by feedback rules that determine government spending, real government debt $B^r_t = B_t/P_t$ and the composition of taxes. In order to pin down the extent to which an increase in government spending is financed by raising consumption and /or labour taxes or by issuing new bonds, we follow Uhlig and Drautzburg [38] and consider a rule of the following form

$$\ln\left(\frac{\tau^n_t}{\tau^n}\right) + \ln\left(\frac{\tau^c_t}{\tau^c}\right) = \psi_T \left[\ln\left(\frac{B^r_t}{B^r}\right) + \ln\left(\frac{\tau^n_t}{\tau^n}\right) + \ln\left(\frac{\tau^c_t}{\tau^c}\right)\right] \tag{30}$$

For $\psi_T = 1$ an increase in government spending is solely tax-financed leaving real government debt unchanged. On the contrary, for $\psi_T = 0$ an increase in government spending is completely financed by new debt.

[12] Bi, Leeper and Leith [9] discuss the alternative between having a monetary policy instrument specified in terms of the risk-free or the risky rate, in presence of a risk premium on government bonds. The second alternative is more common in the literature, but implies a weaker control of inflation. When risk premia are present the central bank faces a dilemma of which rate to target. Actual practice is likely to fall somewhere in between the two alternatives.

The composition of taxes is determined by the following tax rule:

$$\ln\left(\frac{\tau_t^n}{\tau^n}\right) = \psi_\tau \left[\ln\left(\frac{\tau_t^n}{\tau^n}\right) + \ln\left(\frac{\tau_t^c}{\tau^c}\right)\right] \tag{31}$$

The parameter ψ_τ determines to which extent tax financing is done by raising labour taxes τ_t^n instead of consumption taxes τ_t^c. Notice that the limiting case $\psi_\tau = 0$ implies that the direct (labour) tax rate is fixed to its steady state value and tax financing is done solely by raising indirect (consumption) taxes. For $\psi_\tau = 1$, tax financing is completely shifted to labour taxes, leaving consumption taxes unchanged.

Following Leeper [30], we consider government spending rules that are characterized by their degree of responsiveness to the stock of debt, as follows

$$\ln\left(\frac{G_t}{G}\right) = \rho_g \ln\left(\frac{G_{t-1}}{G}\right) - \psi_G \ln\left(\frac{B_t^r}{B^r}\right) + \varepsilon_t^g \tag{32}$$

where ψ_G measures the strength of the endogenous response of government spending to debt and ε_t^g is an exogenous shock.

Leeper [30] classifies as "passive" or "active", respectively, fiscal rules that are or are not reactive enough to stabilize the debt in the long run. We focus on debt-stabilizing rules, but distinguish between "aggressive" ones (rules that achieve stabilization in a short period of time) and "moderate" ones (rules that achieve it in a much longer time); see details below.

The government budget constraint is given by

$$B_t^r = \frac{R_{f,t-1}}{\pi_t} B_{t-1}^r + G_t + K_t^{BG} - \tau_t^c C_t - \tau_t^n \frac{W_t}{P_t} N_t + \tau_t \tag{33}$$

4 Calibration

The parameter values are set so as to be broadly consistent with both the US and euro area data, whenever possible, or taken from the literature. Our benchmark model includes a zero lower bound to fit the post-crisis experience of most industrialized countries; we will further consider, in a later section, the case of the euro area where the ZLB was not hit for a long time after the crisis.

Preferences and production. Time is measured in quarters. We set the coefficient of risk aversion to $\sigma = 1.4$ which is roughly consistent with the value estimated for the euro area and the US (see Smets and Wouters [34],[36]). The degree of habit formation, ξ, is set to 0.5. We set ν equal to 9.75 so as to induce a steady state number of hours worked of 0.3. As usual in New Keynesian models, we calibrate the elasticity of demand, ε, to 6 as this induces a mark-up of 1.2. The discount factor is calibrated to 0.99 so that the annual interest rate is 4%.

We assume a Cobb-Douglas production function $F(\bullet) = K^{\alpha}N^{1-\alpha}$, with $\alpha = 1/3$. The quarterly aggregate capital depreciation rate δ is 0.025. The adjustment cost parameter, $\phi_I = 1/S''$, is set to 1/6, while the utilization cost parameter, $\phi_u = \Psi'/\Psi''$, is set to 1/0.2. These values are roughly in line with the estimates by Smets and Wouters [34], [36] for the euro area and the US.

In order to parameterize the degree of price stickiness ϑ, we observe that by log-linearizing equation 20 we can obtain an elasticity of inflation to real marginal cost (normalized by the steady-state level of output)[13] that takes the form $\frac{\varepsilon-1}{\vartheta}$. This allows a direct comparison with empirical studies on the New-Keynesian Phillips curve using the Calvo-Yun approach[14]. Given $\varepsilon = 6$, the resulting stickiness parameter satisfies $\vartheta = \frac{Y\hat{\vartheta}(\varepsilon-1)}{(1-\hat{\vartheta})(1-\beta\hat{\vartheta})} \approx 65$, where Y is steady-state output.

Bank parameters. To calibrate h we have calculated the average dispersion of corporate returns from the data constructed by Bloom et al. [10], which is around 0.3[15], and multiplied this by the square root of 3, the ratio of the maximum deviation to the standard deviation of a uniform distribution. The result is 0.5. We set the value of h slightly lower, at 0.45, a number that yields a more accurate estimate of the steady state value of the bank deposit ratio.

One way to interpret λ is to see it as the ratio of two present values of the project, the first at the interest rate applied to firms' external finance, the second discounted at the bank internal finance rate (the money market rate). A benchmark estimate can be obtained by taking the historical ratio between the money market rate and the lending rate. In the US over the last 20 years, based on 30-year mortgage loans, this ratio has been around 3 percent, a reasonable value for the lending spread in the euro area as well. This leads to a value of λ around 0.6. Finally we parameterize the survival rate of banks at 0.97. The parameter c can be set looking at statistics on recovery rates for European banks, available from Moody's. These rates tend to vary considerably, from below 50 percent up to 90 percent. We used a conservative 80 percent, which implies $c = 0.2$.

Fiscal policy parameters. The constant fraction of public spending (net of public salaries), G is calibrated so as to match $G/Y = 0.23$. Steady state taxes are set to $\tau^c = 0.17$ and $\tau^n = 0.41$

[13] To produce a slope coefficient directly comparable to the empirical literature on the New Keynesian Phillips curve this elasticity needs to be normalized by the level of output when the price adjustment cost factor is not explicitly proportional to output, as assumed here.

[14] In those studies, the slope coefficient of the log-linear Phillips curve can be expressed as $\frac{(1-\hat{\vartheta})(1-\beta\hat{\vartheta})}{\hat{\vartheta}}$, where $\hat{\vartheta}$ is the probability of not resetting the price in any given period in the Calvo-Yun model. For any given values of ε, which entails a choice of the steady state level of the markup, we can thus build a mapping between the frequency of price adjustment in the Calvo-Yun model $\frac{1}{1-\hat{\vartheta}}$ and the degree of price stickiness ϑ in the Rotemberg setup. The recent New Keynesian literature has usually considered a frequency of price adjustment of about a year as realistic. We use a slightly higher value, probably more realistic for the euro area, and parameterize $\frac{1}{1-\hat{\vartheta}} = 5$, which implies $\hat{\vartheta} = 0.8$. Note that since our model equations are log-linearized there is no difference in the dynamics of the model between Rotemberg and Calvo approaches.

[15] This value is not dissimilar to that obtained from the RoA of US banks over the long run, e.g. calculated from the data reported by the St Louis Fed, see http://research.stlouisfed.org/fred2/series/USROA.

which are values calculated for the euro area by Trabandt and Uhlig [37]. The steady state value of government debt is set to $B^r/Y = 0.7$.

For baseline crisis scenario, the fiscal feedback rules are calibrated as follows. ψ_τ is set to 2/3 implying a mix of direct and indirect taxes, consistent with the composition of taxes in the euro area (the number for the US is comparable, if one considers both federal and state and local governments).[16] The responsiveness of government spending to debt is set to $\psi_G = 0$ implying, as in most of the literature, an exogenous process for government spending. The autocorrelation of government spending is assumed to be 0.9, consistent with estimates in the literature. The value $\psi_T = 0.1$ ensures the dynamic stability of public debt, but only in the very long run.

Monetary policy parameters. The weight on inflation in Taylor rule, ϕ_π, is set equal to 1.5 and the output coefficient, ϕ_y, is set equal to 0.5/4. We set the interest rate smoothing parameter, ϕ_r, equal to 0.6.

Constructing the exit strategies

Our simulation strategy is as follows. We first construct a scenario that mimics the actual situation experienced during the 2007-2008 crisis, see details in the next section. We call this the baseline crisis scenario. Then, starting from this, we calculate the effects of different exit strategies, each embodying a different mix of monetary and fiscal policy. Fiscal exit strategies consist in the adoption of alternative fiscal rules, differing in their degree of aggressiveness, the sequencing of policies, the composition of fiscal adjustment and the extent to which the change in the policy is expected.

Monetary policy. Monetary policy is either at the ZLB[17], in which case the short term rate remains constant at zero, or follows the Taylor rule just described. Under a standard Taylor rule with $\phi_r = 0.6$, the interest rate touches the ZLB immediately in all crisis scenarios. The exit from the ZLB takes place endogenously; the timing of monetary exit varies depending on the fiscal strategy. We also consider a case of "late" monetary exit, where the exit time is exogenously delayed by 4 quarters. Finally, in the final section we check the robustness of our results to a different monetary policy regime in which the ZLB is avoided by raising the smoothing parameter. We argue that this regime is more akin to the policy approach followed by the ECB.

[16] Notice that total fiscal revenues in the euro area are about 45 percent of GDP, of which about two thirds are composed by direct taxes and social security contribution on individuals and corporations. The remaining fraction is indirect taxes. Both direct taxes and social security contributions can be regarded as labour-related levies.

[17] We do not model here any "quantitative easying effects" from liquidity injections: this would indeed require an explicit modeling of open market operations, with counterparty risks and collateral constraints. Our focus being different, we decided to neglect this aspect.

Fiscal policy. As mentioned, in our baseline crisis scenario we assume an "unresponsive" public spending rule ($\psi_G = 0$), and a "low-response" tax rule ($\psi_T = 0.1$). In all other scenarios, these fiscal policy rules are replaced by new and more "responsive" rules at a given time; we regard this as the exit time for fiscal policy. In our "standard timing" case, the fiscal exit happens at quarter $t = 9$[18]. The exit is unanticipated if agents have no information about it before it occurs. It is anticipated if the authority credibly announces at $t = 0$ that it will switch to the new rule at a pre-announced quarter.

Fiscal rule parameters. Our fiscal reaction rules differ for their degree of "aggressiveness", measured by the parameter of the tax rule (more aggressive means a higher ψ_T) or the government spending rule (more aggressive means a higher ψ_G). Our "moderate" fiscal exit policy has the property that the deviation of the debt-to-output ratio from its pre-crisis level is eliminated (within a tolerance margin of one percent) in period $t = 200$, i.e. after 50 years. Conversely, we call "aggressive" a policy where the same debt stabilization objective is reached in $t = 40$, i.e. after 10 years[19]). The calibration of ψ_T and ψ_G is as follows: we find that in the case of an unannounced change in the tax rule alone, under an unresponsive spending rule, $\psi_T = 0.22$ implies a moderate fiscal exit, whereas $\psi_T = 0.56$ implies an aggressive fiscal exit. In the case of an isolated change in the spending rule combined with a low-response tax rule, $\psi_G = 0.008$ and $\psi_G = 0.04$ imply a moderate and aggressive fiscal exit, respectively.

Sequencing and pre-announcement. We consider cases where fiscal policy moves early or late by 4 quarters, respectively at $t = 5$ or $t = 13$. Concerning monetary policy, we included also a simulation where the central bank keeps the interest rate at zero for another year following the exit time from ZLB predicted by the Taylor rule; we call this scenario "late monetary exit".

Taxation. We also considered different types of taxation. Whereas in all our scenario we assume $\psi_\tau = 2/3$, we also explore the limiting cases $\psi_\tau = 0$ and $\psi_\tau = 1$. Thereby, we assume that alongside with an announced or unannounced switch to moderate/aggressive fiscal policy at $t = 9$, the composition of taxes changes. The case $\psi_\tau = 0$ implies that at $t = 9$, the labour tax rate jumps to its steady state level and the government budget is consolidated solely by raising indirect (consumption) taxes. In the other limiting case $\psi_\tau = 1$, the fiscal consolidation is done by raising direct (labour) taxes.

[18] A fiscal exit two years, after the crisis hits, seems reasonable at least for the euro area. The Stability Programs approved by Ecofin envisaged for most euro area countries a fiscal consolidation program beginning in 2011.

[19] The IMF staff has designed long term scenarios of fiscal consolidation for the advanced G20 countries (see [29]). The scenarios are based on a target of returning to a debt to output ratio below 60 percent by 2030. They assume that the exit process starts in 2011, when the debt ratio for the aggregate they consider, is projected to be above 80 percent. In their scenario, the debt level would return to this level around 2021, i.e 10 years after the fiscal exit starts. Hence, our "aggressive" strategy is consistent with the IMF projections.

5 Baseline: crisis and initial stimulus

Our baseline simulation incorporates two elements: a set of shocks to the financial system, reproducing the initial factors that generated the crisis, and a number of policy interventions, representing the supporting measures (monetary, fiscal and financial) adopted as an immediate response to the financial turmoil. Our aim is to model the main forces driving the macroeconomic variables before the exit strategies are initiated.

The crisis. The first set of shock includes three components: a persistent increase in the riskiness of investment for banks (parameter h); a persistent decrease in the early liquidation value of bank investment (parameter λ); a destruction of bank capital. The first expresses the increase in risk perception observed since late 2008. We calibrated this shock so as to mimic the increase in the US and euro area average implicit stock market volatility. The second expresses the increase in the relative riskiness of non-prime borrowers in non-intermediated (bond) debt markets over the same period. We calibrated so as to match the increase in spread between A and AA corporate bond yields (in relative terms, the increase was more or less equivalent in the euro area and in the US). The third shock, the reduction of bank capital, is calibrated so as to attain an overall bank capital deterioration equivalent in percent to that of euro area banks[20].

Formally the three shocks are written as follows:

$$\begin{aligned}
\ln\left(\frac{h_t}{h}\right) &= 0.85\ln\left(\frac{h_{t-1}}{h}\right)+\varepsilon_t^h\,, \quad \text{where } \varepsilon_0^h = 0.22,\\
\ln\left(\frac{\lambda_t}{\lambda}\right) &= 0.85\ln\left(\frac{\lambda_{t-1}}{\lambda}\right)+\varepsilon_t^\lambda\,, \quad \text{where } \varepsilon_0^\lambda = -0.24,\\
K_t^B &= (1-d_t)Q_tK_t\exp(u_t^B)\,,\\
u_t^B &= 0.95u_{t-1}^B+\varepsilon_t^B\,, \quad \text{where } \varepsilon_0^B = -0.2\,.
\end{aligned}$$

The initial stimulus. The other element introduced simultaneously in the baseline crisis case is a set of policy measures intended to provide a first response to the contractionary effect of the crisis and to the increase in bank risk. The short term interest rate, following the Taylor rule, hits the ZLB immediately and remains there until the endogenous monetary exit. The tax and spending rules are set at respectively their low-response or no-response mode, and government spending increases by 5 percent of GDP ($\varepsilon_0^g = 0.05Y$). To appreciate the effects of this type of fiscal expansion, we also consider a variant where public spending does not increase. Finally, a third policy is a bank capital support policy. We assume that the government intervenes to refinance

[20]The impact on the capital/asset ratio of US banks was substantially greater; see IMF [29].

the bank capital, when their capital/asset ratio is below the steady state.[21] The recapitalization increases the budget deficit as it is financed partly by debt, according to the above rules. Formally:

$$\ln\left(\frac{K_t^{BG}}{K^{BG}}\right) = 0.7\ln\left(\frac{d_t}{d}\right)$$

Again, to appreciate the effects of this "unconventional" type of fiscal expansion, we also consider a variant where publicly funded bank recap policy is not activated.

Simulation profiles. Subject to these shocks and these policy rules, the model produces profiles for the main variables depicted in figure 1. Start first with the case in which both types of fiscal support are activated. There is an immediate and strong contractionary effect on output, driven by investment, due to a combination of interest rate and balance sheet channels. Inflation drops sharply on impact, then bounces back. The interest rate hits the ZLB immediately, returning to positive values after 7 quarters. The budget deficit rises on impact, increasing the debt ratio by about 10 percentage points after a short lag. This increase is relatively small due to the simplifying assumption that all debt is short term, hence it immediately reflects the decline in the interest rate; a longer maturity would amplify the increase in the debt-to-output ratio. In the long run (lower panel in the same figure), the debt-to-output ratio returns back to its initial value very slowly, given the slow debt adjustment mechanism implicit in the fiscal policy functions.

In the financial sector, bank riskiness rises and remains high for several years, following the destruction in bank capital and the increase in leverage caused by the reduction of interest rates (risk-taking channel). The increase in risk is contractionary as it raises project liquidation and risk premia, hence it slows the subsequent recovery of investment and output. Lending rates are less responsive than money market rates because following a monetary accommodation bank risk increases, hence the risk premium increases. Low interest rates increase the probability of a run, thus they implicitly reduce the states in which depositors get repaid. Bank recapitalization by the public sector kicks in immediately, helping a more rapid recovery of bank balance sheets. One can observe in the figure that both types of fiscal expansion (conventional and unconventional) contribute to dampening the initial decline in output. The bank support policy is particularly effective; interestingly, its expansionary effect is strong enough to lead to a reduction of the debt-to-output ratio. Note that the removal of bank support policy in the short run (8 quarters) produces

[21] In steady state, the government limits itself to transferring capital from the old to the new generation of bank capitalists. Note that we model bank support in form of a public transfer aimed at financing the subscription of capital by the private sector, rather than direct equity subscription by the state. This mimics a form of bail-out frequently used in Europe – with the exception of the few cases of outright nationalization. This approach may also capture some features of the US bank support policy during the crisis, which consisted also in providing non-equity funding at discounted rates.

a slight *decrease* in bank risk. Under public recapitalization banks receive bank capital at a discount compared to the one paid to bank capitalists; as a result banks shift toward short term liabilities, increasing the probability of bank runs. On the contrary, the removal of public bank support tilts the balance of the trade-off and restores market discipline. Intuitively, even though banks are less capitalized without public support, their return on assets is higher, and this is enough to generate, on balance, a higher probability of solvency. Banks effectively protect their balance sheets via higher lending rates, at the cost of an additional recessionary impulse to the economy.

To analyse how close our initial scenario is to actual data, in table 1 we report model-generated and actual post-crisis data for the euro area and the US. We suppose that the crisis hits between 2007 and 2008, hence the first full year after the shock in the model coincides with 2009; this is a approximation, because the impact of the financial crisis was not concentrated in a single quarter but spread out over a period ranging at least between August 2007 and end-2008. Moreover, the entries are not directly comparable, because the OECD data are generally expressed in percentage changes, whereas the model results are deviations from steady state. The numbers are comparable only if the starting values are close to the steady state (a realistic assumption for 2007-2008), and if the steady state values remain constant (more questionable). In 2009 GDP declined by 4.4 percent in the euro area and by 3.1 in the US; in terms of output gap, the decline in the 2007-2009 period is 6.7 percent in the euro area and 5.0 in the US, against 7.7 predicted by the model. Investment in 2009 falls by 12.7 in the euro area and 15.3 in the US against 11.6 percent in the model. In 2010, the model predicts a small recovery in investment (remember again that the numbers are expressed in deviations from steady state, so an increase means a recovery even if the number remains negative); historically, investment was stagnant. On public finance, the match is rather good in the first year, while in the second the model under-predicts the deficit and the increase in debt, again due to the simplifying assumption that all the debt is short term. Consider now the matching for inflation. It should be taken into account that inflation before the crisis was rather high and rising, in both the euro area and the US. If we look at annualized quarterly figures and compare peak-to-trough values, the numbers for the US reported in the table are 9.1 in 2008 and -2.0 in 2009, a drop of 11.1 percent, and in the euro area 6.7 and -2.7, a drop of 9.4 percent. Our simulated drop is 11.5 percent.

It should be noted that our model provides only a partial explanation of the inflation process, excluding all imported components; the latter, in any event, do not seem overly relevant in explaining post-crisis inflation developments in either the US or the euro area. To match inflation results we used headline inflation (PCE is the monetary policy target in the US, harmonised CPI in the euro area), which fell rather sharply after the crisis in both areas, not core inflation, which

did not, and whose dynamics over the crisis years the model fails to match. Ball and Mazumder [7] regard the post-crisis reaction of US core inflation as puzzling, in that it fell much less than implied by a standard Phillips curve, attributing this phenomenon to a mismeasurement of core inflation and to a change in the Phillips curve. They note that other measures of underlying inflation, like the weighted median of Bryan and Cecchetti [13], declined more than the traditional ex-food-and-energy measure. Moreover, Stock [35] shows that headline measures are not affected by the puzzle.

6 Exit from fiscal and monetary stimulus

We conducted a number of simulation experiments organized around four interrelated questions. The first concerns the speed at which the policy stimulus is withdrawn. Specifically, we examined alternatives concerning how fast fiscal consolidation is achieved, as a result of more or less "aggressive" fiscal reaction functions, in terms of the response of government spending or taxes to the level of debt. The second question concerns the composition of fiscal adjustment; we compared programs based on spending cuts or tax increases; within the former we distinguish exit from conventional fiscal expansions (i.e. based on spending or taxes) from "unconventional" ones, i.e. exit from bank support policies; within the latter we considered policies tilted more towards labour or consumption taxes. The third question relates to communication, specifically whether the change in the fiscal rule is credibly announced or not. Lastly, we examined the issue of policy sequencing and delaying. In particular, we compared options where fiscal policy moves earlier or later relative to our standard timing case, and also examined a case where the central bank maintains the interest rate at zero for a longer time than implied by the Taylor rule.

We present our results in two formats. First, we look at the profiles of the main macro variables over 30 and 200 quarters (figures 2 to 6); the first horizon is relevant for cyclical effects, the second helps appreciate certain low frequency phenomena like public debt dynamics. Second, in table 2 we present indicators measuring the intertemporal effects of exit strategies on output, inflation and bank risk over a given time horizon, distinguishing short from long run effects. The criteria are the discounted deviations of output, and the discounted root mean squared deviations of bank risk and inflation, for each exit strategy relative to the baseline crisis case, as a percent of the deviation of such case from no-crisis steady state. In this way we measure how much each strategy brings the profile of the macro variables back towards the steady state, in percent of the distance between the baseline crisis and the steady state. The baseline crisis case is reported on top of the table; the criteria there are calculated relative to the steady state. Note that while for output we penalize

negative deviations, in the case of bank risk and inflation we penalize deviation in both directions. This is based on a presumption that the steady state incorporates optimal or somehow desirable values of these two variables.

Moreover, in the table we also report the welfare measure consistent with the model, a function of intertemporal consumption and leisure weighted with our assumed preference parameters. Our welfare metric is the fraction of consumption that would be needed to equate conditional welfare under the baseline crisis scenario to the level of welfare implied by the assumed exit strategy. Such fraction, Ω^e, is defined by:

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left((1+\Omega^e)C_t^b, (1+\Omega^e)C_{t-1}^b, N_t^b\right) = E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t^e, C_{t-1}^e, N_t^e\right)$$

where the superscript b stands for the baseline crisis scenario and the superscript e stands for the exit strategy considered. If Ω^e is positive, the exit strategy produces an increase in welfare; and viceversa. The welfare measure is consistent with the model, but has the drawback of depending on the utility function used.

To start with, in figure 2 we assume that the "conventional" fiscal accommodation (conventional means enacted through taxes and/or public spending) is removed unexpectedly at quarter 9, our standard timing. We assume here that the adjustment program is expenditures-based. The moderate and the aggressive exit strategies are plotted against the baseline crisis case. Moreover, we also plot a line where we assume the exit from both conventional and unconventional fiscal policies (this one meaning bank support policy), at the same quarter.

The decline in public spending leads to a rather moderate contraction of output, thanks to some crowding in of private expenditure[22]. The fall of output and employment increases marginal product and, in equilibrium, real marginal costs, hence inflation rises on impact. Responding to the higher inflation profile, monetary policy (which exits the ZLB at quarter 7, as reported in the last column of table 2) increases real rates, more sharply in the aggressive case. The monetary restriction reduces bank risk through the risk-taking channel of monetary policy. The decline of bank risk seems small in the plots, but it is protracted and its role in the model is significant. In the short term the outcome of this exit strategy is lower output, more inflation and more monetary restriction, a safer financial system and, of course, less public spending and lower budget deficit and debt accumulation. All this occurs more sharply in the aggressive scenario. As a result, tax rates, driven by their reaction functions, move back to steady state more quickly. The long term effects of the strategies are better appreciated in figure 3. There we see that the policy activism is rewarded

[22]Note that the crowding in of private expenditures could be reduced, under imperfect markets, by deleveraging in the household sector. We do not consider this element, which could slow down the recovery of the economy.

by higher output and consumption beyond (approximately) 30 quarters, more so and earlier with the aggressive mode. The long term implications for public finance are radically different. The aggressive strategy trades in a more intense, but short lived, spending squeeze for a slower debt dynamics and permanently lower labour and consumption tax rates. Finally, note that exiting from the bank support policy reduces, as one expects, the debt ratio, but only marginally, and has small effects on the macro-variables and bank risk.

To better appreciate the role of the banking sector in the model, table 3 reports the fiscal multipliers, both in the long term – infinite horizon, table 3a – and in a short term – 20 quarters, table 3b – under different fiscal rules (baseline with low or no reaction, or aggressive, based on spending or taxes)[23]. We distinguish between our model and a plain-vanilla model without banking, obtained by stripping the banking equations and letting the monetary transmission occur only via the money market determined rate R_t. The table shows that the long run multiplier is close to zero under a baseline with low or no reaction fiscal rule, but positive and quite sizeable under an aggressive one (0.94). The multipliers depend quite strongly on the fiscal rule. Rules pursuing fiscal sustainability more strongly result in higher multipliers because a stronger consolidation now reduces the need for future distortionary taxation. Multipliers tend to be higher under a spending rule than under a tax rule, as expected, because higher taxes dampen the expansionary effect. Under an aggressive spending rule, the multipliers are quite high (between 1 and 2), both in the short and in the long run. Finally, note that the multipliers of the model with banking are higher than those of the alternative model. There are two reasons for this. First, following a positive spending shock the crowding out of private investment is stronger in the model without banking. In that model, the asset price drop directly impacts on investment behavior, whereas in our model the key transmission variable is the real bank lending rate $\frac{R_{A,t+1}}{\pi_{t+1}}$, which does indeed rise, hence inducing some crowding out, but moderately. The intermediation by the bank tends to dampen the impact of the shock on the firm, a result that reminds that noted by Pedersen and Rajan [32] with reference to monetary policy. The second reason is that the profile of interest rates in the model without banking is on average higher than with the other model, hence public debt accumulation is higher, and this implies, under our financing assumption, higher labour taxes in the medium-long term.

We move now to figure 4, showing the consequences of announcing the fiscal exit, considering spending-based aggressive strategies. Note that this exercise is counter-factual, because we assume

[23]The multipliers are calculated as net present value of all future output deviations from baseline divided by the net present value of all future public spending deviations from baseline, following a public spending shock. To mimic the conditions prevailing in our analysis of exit strategy, we keep the interest rate constant for 7 quarters. So these are akin to "liquidity trap" multipliers.

that pre-announcement takes place immediately after the crisis together with the launch of the supporting policies. In fact, an announcement of this kind was not made in any country, for fear that it could reduce the effectiveness of the stimulus. Our result suggest that such concern may have been misplaced. The improvement in macro performance from announcement is very significant, as seen in the charts. Announcement reduces the initial output loss by nearly a half, and the consumption loss also quite significantly. The pre-announcement reduces the initial deflation and avoids the spike in inflation observed in the spending strategy at the time of exit. Hence, the intensity of the monetary restriction is reduced. Though public spending declines less, debt consolidation is faster, as we can appreciate in panel [4;2] of the figure.

In table 2 we report, with reference to the ad-hoc criteria, gains (positive numbers) and losses (negative numbers) from adopting each exit strategy relative to not exiting at all, in percent of the loss under the baseline crisis case. The welfare gain/loss is calculated with the formula given above. The loss of the baseline crisis scenario, relative to the no-crisis steady-state, is reported on top of the table (in the case of welfare, we report the absolute lifetime discounted utility). To help get a visual impression, we have filled in green (light or dark) the gains and in red (light or dark) the losses. White cells denote little or no effect. First, the baseline crisis case, without fiscal consolidation (either moderate or aggressive), entails very substantial costs relative to the no-crisis steady state. The total discounted output loss in the first 20 quarters is 36 percent of yearly output, and the total loss is 55 percent. Measured at annual rate, the permanent output loss is 2.2 percent (0.55 divided by the infinite discount factor at a 4 percent interest rate). In terms of bank risk and inflation, the loss is in the order of 18 percent.

The gain from announcement emerges from the ad-hoc performance measures of table 2. The announced, aggressive strategy based on spending results in an improvement in performance based on virtually all criteria, at both short and long term horizon. The gain is stronger for output and inflation. If the exit is not announced, the moderate and aggressive spending-based strategies do not produce appreciable benefits relative to the crisis baseline case in the short run. In the long run there is an improvement, particularly with regards to output, but it is a limited one. The picture changes under the announced aggressive policy: the fiscal exit strategy produces gains at both time horizons. The gains obtained with a tax-based consolidation strategy are broadly balanced with those obtained through a spending-based strategy. Remember that the tax-based strategy entails an increase in both labour and consumption taxes over time, to stabilize the debt. In both cases, the timing of the exit of monetary policy from the ZLB is anticipated, due to the better macro performance. In the tax-base strategy, the higher inflation profile results in an exit at quarter 4, in the spending-based one at quarter 5.

Note that, if the welfare measure is considered, surprise strategies are generally superior. This clearly derives from weighing leisure alongside with consumption in the utility function: strategies that produce higher consumption and output tend to be superior based on our ad-hoc criteria, while they may well be welfare-inferior due to the decrease in leisure that the exit policy produces. In view of these results, the ad-hoc criteria provide a more meaningful yardstick for ranking the policy alternatives, especially in presence of the large unemployment experienced after the crisis.

Consider now figure 5, where we compare alternative timings for the fiscal exit. In one case the switch of the fiscal rule to the aggressive mode happens 4 quarters earlier than in the standard timing case (i.e. at quarter 5 instead of 9), in the other it takes place 4 quarters later than in the standard timing case. In all cases the fiscal consolidation is fully anticipated. The modality of the fiscal exit are quite apparent in the charts representing government spending, the public deficit and debt. The main implication of these timing differences in the stance of monetary policy; the exit from the ZLB takes place at quarter 5 in all cases, but the subsequent degree of monetary restriction is higher if the fiscal exit is delayed. This depends on the effect of the late fiscal stabilization on inflation and output. Note, in passing, that this figure also gives an idea of the sensitivity of the results to change in our timing assumptions. Each line differs from the adjacent one due to the 4-quarters difference in the exit time, hence one can see roughly how much each line would move by moving backward or forward the timing of exit by one or two quarters.[24]

The timing of both fiscal and monetary exit for each scenario is reported in the last column of table 2. Here we see that the early fiscal exit option performs quite well, at long horizons, based on the ad-hoc criteria, relative to both the standard timing and particularly the late option. According to all criteria there is a gain at long horizons. In the short run, results are more nuanced. An early fiscal exit based on spending cuts results in output losses, compared to the baseline timing assumption (see table 2, columns "20 quarters" and figure 5). Notice that the government now cuts spending in most cases before the ZLB stops being binding. This is associated with a larger (negative) fiscal multiplier, consistent with results of Eggertsson [24] and Christiano, Eichenbaum and Rebelo [16]. The negative short-run output effects of an early exit are more than outweighed by the beneficial long-run effects of lower taxes and a safer financial system, resulting in a superior performance of the early option at long horizons (see table 2, columns "All quarters"). In contrast, an early tax-based fiscal consolidation results in output gains even in the short-run when the ZLB is binding.[25] As taxes increase and the nominal rate is fixed at zero, the real rates fall. In our model

[24]The results are qualitatively unchanged if one experiments with further delayed fiscal exists; the results are available on request.

[25]See table 2 and figures 17 and 19 in the Web Appendix which compare the responses of early, baseline and late moderate and aggressive taxed-based strategies, respectively.

this is expansionary for two reasons. First it boosts investment directly and second, by raising asset prices, it also boosts banks' balance sheets values and credit. Notice that the expansionary effects of tax increases are consistent with results highlighted in Eggertsson [24] in the case of a traditional New Keynesian model, however in our model the expansionary effects are amplified by the credit channel.[26]

We now consider the case of a delayed monetary exit. We obtain this by forcing the interest rate to remain at the ZLB for 4 quarters more than implicit in the rule. We want to see if there can be benefit from prolonging the monetary expansion beyond what implicit in the Taylor rule. The answer seems to be yes; see figure 6. Output returns to the steady state much earlier, and the budget deficit and debt accumulation are more contained. A loss in terms of bank riskiness is visible, but seems rather limited; remember that the extra monetary expansion lasts only a year. Table 2 shows that the scores for this option are favorable, and in fact in terms of output (both short and long term) they are the best of the whole table. The tax-based and spending-based strategy perform equally well in this case. This may appear surprising in light of our earlier results. In the case of a delayed monetary exit, both strategies (spending-based and tax-based early fiscal exit) are superior in terms of the output criteria, even in the short-run. The difference can be explained by the different monetary strategy. In the early fiscal scenario, monetary policy follows the Taylor rule. With a delayed monetary exit, the central bank uses forward guidance, committing to keep the interest rate low for a longer period than implicit in the Taylor rule. This fuels inflation expectations which in turn lowers real interest rates and induces investment to rise. Consumption rises too, due to falling real interest rates and taxes, as can be seen in figure 6. In the case of a spending-based strategy, the rise in investment outweighs the negative impacts of the drop in government spending. As a result, output rises. In the case of a tax-based strategy, the expansionary effects of forward guidance are amplified by the expansionary effects of tax hikes when the interest rate is at the ZLB. This explains why, when the focus lies on the unannounced mode, an aggressive tax-based strategy outperforms all other options.

The basic message from the experiments conducted with these alternative timing assumptions can be expressed as follows. A fiscal exit before the ZLB stops being binding is generally beneficial, with some qualifications. The performance tends to be even better when fiscal policy exits earlier rather than later. As we summarized in the introduction, in most cases strategies in which fiscal policy abandons the accommodative stance before monetary policy tend to dominate. Is crucial

[26] Our model structure would allow a detailed comparative analysis of different fiscal policy compositions; in principle, as suggested by a referee, one could go as far as determining what combinations of equity injections and traditional government spending are optimal along the exit path. We leave this to future research.

that exit happens after its announcement and, regardless of the announcement, after the crisis hits; see our figure 1 and related comments, where we show that a looser fiscal policy (either conventional or unconventional) helps smoothing the output drop after the bad shock (further results in this direction are available on request). If policy-makers penalize sharp output losses it pays to use fiscal as well as monetary policy in the short run to dampen the crisis, hence shifting the question to the appropriate exit time.

Finally, we consider the exit from bank support policy, by reducing to zero (from 0.7) the response of bank recapitalization to the deposit ratio. The improvements obtained relative to the exit from the conventional fiscal expansion alone are not appreciable – compare the last lines in the table with the corresponding ones in the section on top, marked "baseline exit". We note, however, that the gains tend to be more visible if the exit from the conventional fiscal expansion does not produce good results – for example, because it is unannounced. Moreover, the exit from bank support is clearly inferior in terms of welfare.

To summarize, three general observations emerge. First, nearly all exit strategies, regardless of their characteristics, improve over the baseline crisis case in terms of long term performance. In the short term, the advantage is more mixed, if the exit strategy is not credibly communicated in advance. Second, the announced strategies are clearly superior based on ad-hoc criteria, but somewhat inferior based on welfare, due to their effect on unemployment (which the welfare criterion identifies as leisure). The best strategies are announced (or unannounced, if one considers welfare) and generally aggressive. The choice between spending-based and tax-based consolidation is more nuanced and depends on individual scenarios[27]. Thirdly, sequenced strategies, with fiscal policy exiting early and monetary policy, if necessary, maintaining low rates for a somewhat longer time, perform somewhat better than strategies involving the simultaneous exit of fiscal and monetary policy. The result that keeping rates low longer than the Taylor rule would prescribe might perform better is in line with Werning [39]. This result holds despite the fact that expansionary monetary policy triggers increases in bank risks and in the associated resource costs.

One last consideration concerns the parallel between our exit strategies and the redistributive role of monetary policies, emphasized in other parts of the literature (see Brunnermeier and Sannikov [12]). In our model expansionary monetary policies redistribute resources from depositors to bankers: the low interest rates reduce the returns accruing to depositors and reduce banks' liability services. Also, as low interest rates increase the probability of a run due to the risk-taking channel,

[27]There are widely different views on this. Alesina and Ardagna [6] have shown empirically that government cuts are more beneficial than tax cuts, while Batini, Callegari and Melina [8] more recently show the opposite. Erceg and Linde [25] find that tax-based consolidations can improve upon spending-based ones if the ZLB binds; we return to this result below, when we examine the no-ZLB case.

they implicitly reduce the states in which depositors get repaid. In the short run this redistributive effect also induces an implicit banks' recapitalization and provides an additional reasons for keeping the interest at zero for longer periods.

7 Eschewing the zero-lower-bound

We now examine a monetary policy strategy that prevents the short-term interest rate from hitting the ZLB. As already seen, in our model under macroeconomic scenarios that mimic the recessionary environment of 2009 and 2010 a conventional Taylor rule generates interest rates that drop to zero immediately and stay there for about 2 to 3 years, depending on the fiscal strategy. However, central banks may not wish to let interest rates to go that low. Three reasons for this have been evoked by the ECB (see Coeure [17]). First, low or zero money market rates hurt bank revenues, reducing them more than funding costs. This discourages market-making activity (in fact, interbank transactions dried up during the peaks of the crisis in Europe, and have not fully recovered ever since) and can, in extreme cases, drive intermediaries out of business thus endangering financial stability. Second, linked to the previous point, low rates encourage search for yields and risk-taking – a point made elsewhere in this paper. Thirdly, zero interest rates, especially if combined with "forward guidance" (the practice of announcing the intention to keep interest rates at zero for a long time, conditional on the macroeconomic environment), entail communication and credibility challenges for central banks.

As argued in past literature, fiscal multipliers can be higher in a ZLB environment; hence it may be important to check if our results obtained under ZLB are robust to policy settings where the ZLB is avoided. We mimic this situation by elevating somewhat, relative to the previous analysis, the smoothness parameter in the interest rate rule, so that the interest rate does not fall to zero immediately but moves gradually towards that level without a tendency to go below the boundary[28]. This seems akin to the approach followed by the ECB, which engineered progressively lower but still positive rates during 2009-2011, eventually moving to a near-zero level for the daily interbank market reference rate EONIA only late in 2012.

The full set of charts for the no-ZLB case, corresponding to figures 2 to 5, are available in the Web Appendix. In substance, our results are broadly unchanged. However, the differences in performance across alternative strategies are more nuanced. A more persistent and history-dependent interest rate tends to reduce the differential impact of fiscal policy. In order to get

[28]The smoothness parameter needs to be elevated from 0.6 to 0.83 in order to obtain this result. With this value, in our standard crisis scenario, the interest rate declines gradually, approaching zero to then rising again once the economy recovers.

a sense of the results we report, in tables 4 and 5 the equivalent of tables 2 and 3 but with the alternative monetary rule avoiding the ZLB (note that in table 4 the rows "Late monetary exit" are eliminated and the last column, showing the timing of exit, are eliminated, since there is no longer a ZLB). As one can see, the central feature of the previous results is preserved, namely, fiscal exit strategies improve upon the baseline crisis scenario, almost regardless of the type of fiscal strategy chosen. However, if one focuses on the output criterion, this is true mainly in the long term, whereas in the short term the traditional Keynesian contractionary effect of fiscal consolidation prevails. Similar results, slightly more nuanced, are obtained for inflation and bank risk. The same result obtains for the welfare criterion: fiscal exit strategies improve welfare in the long run (short term results, not reported in the table, show negligible welfare effects). The contrast between the welfare and ad-hoc criteria becomes more interesting when one compares tax-based versus spending-based consolidation strategies. Spending-based strategies are consistently better on welfare terms, but tax-based ones tend to be better in terms of output (and, to a lesser extent, the other ad-hoc criteria). Especially noteworthy is the contrast between the tax-based strategy effects in the short run: the output effect is expansionary if the ZLB is binding, contractionary if it is not. This echoes, in addition to the result of Eggertsson [24] already mentioned, that reported by Erceg and Linde [25], according to which tax based consolidations are less detrimental if the zero bound constraint on interest rates is binding. Note, in addition, that unlike in the earlier case, it is no longer so clear under no-ZLB that announced fiscal exits are superior to surprise ones, based on welfare as well as on the ad-hoc criteria. More generally, a major difference with the ZLB case is that the differential performance across different exit strategies are less evident. The maximum welfare increase attainable by an exit strategy is measured by 0.34 percent of household consumption, whereas in the previous case was more than double this amount.

Table 5 shows the same multipliers as in table 3, but this time without ZLB. The results confirm that outside of the ZLB the multipliers tend to be lower, under an aggressive fiscal exit. For example the long-run spending (tax) multiplier in the banking model is 0.96 (0.51), whereas previously it was 1.59 (1.15). Under an unresponsive or low-response fiscal strategy, as the one incorporated in our baseline crisis case, the difference is not appreciable, confirming that, as noted already, one-time fiscal shocks are more effective if the fiscal policy strategy is clearly sustainable in the long-run.

8 Conclusions

Research on exit strategies is an infant industry; in spite of its interest and practical relevance, very few authors have explored the topic. To our knowledge, this is the only paper that approaches the issue directly rather than studying parts of it, like the size of fiscal multipliers or the phasing out of unconventional monetary instruments.

Our analysis could be enhanced in at least three respects. First, we limit ourselves here to examining either fully unanticipated, or fully and credibly pre-announced strategies. It would seem realistic to think instead in terms of a continuum of intermediate situations, characterized by incomplete or only partly credible announcements. The stochastic regime switching methods of e.g. Davig and Leeper [19] seem a natural way to approach the problem, though applying them to a complex model like ours presents serious technical obstacles.

Second, our model could benefit from a few additional elements of realism, although they would come at the cost of additional intricacy in the model structure. We mention three here: (1) introducing long term government bonds and a term structure of interest rates, (2) introducing sovereign risk and a corresponding risk premium, and finally (3) contemplating a specific role for household leverage in influencing consumer behavior. These elements would affect the results in opposite directions: the first, as we already discussed, would increase the initial build up of public debt and therefore tend to favor an earlier fiscal exit; the second would increase the gains from early fiscal adjustment by reducing the sovereign risk premium; the last would reduce the crowding in of private expenditures following a fiscal restriction, hence making, ceteris paribus, an early fiscal exit more costly.

Finally, the distinct superiority of aggressive and pre-announced (but appropriately timed) exit rules depends on the assumption of fully forward-looking agents. In presence of uncertainty, rule of thumb behavior or learning it is probable that some of our sharp results would be weakened. It would be interesting, in this respect, to establish a mapping between the benefits obtainable from credible fiscal announcements and their informational requirements.

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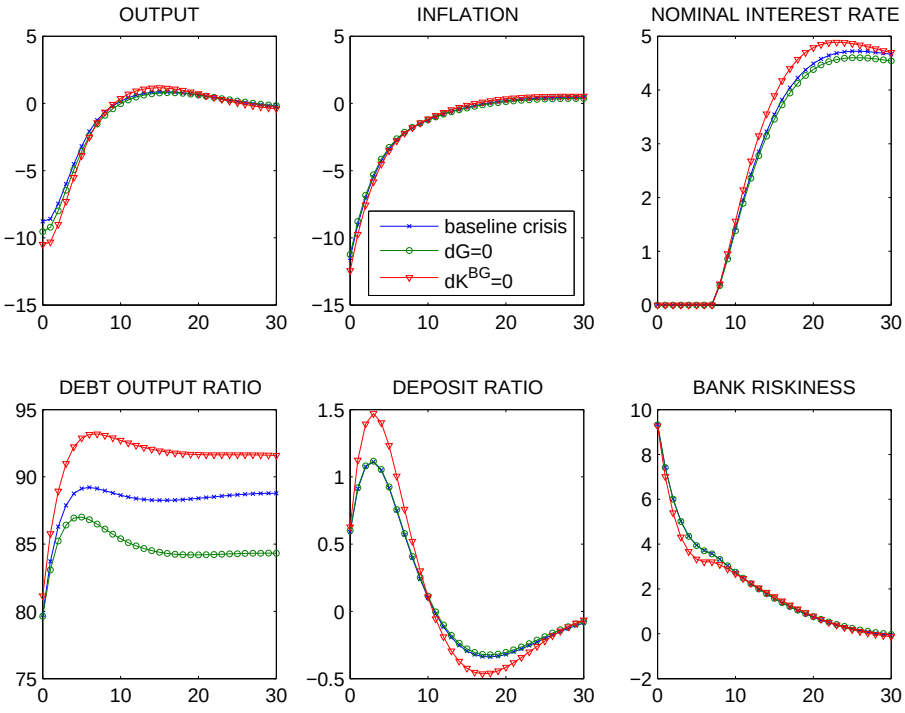
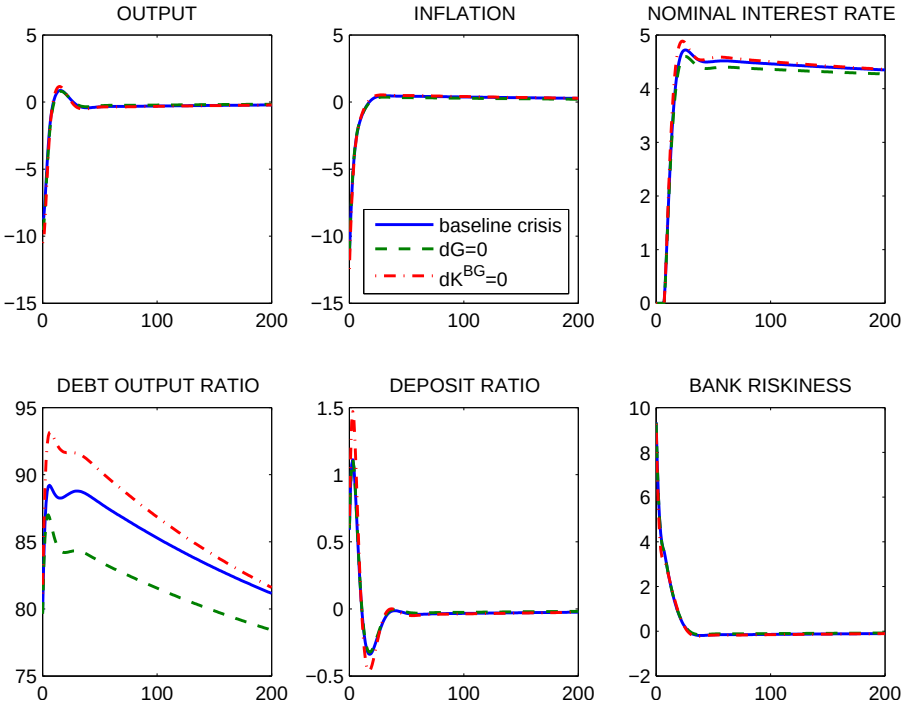


(a) Short run horizon



(b) Long run horizon

Figure 1: Crisis and initial stimulus

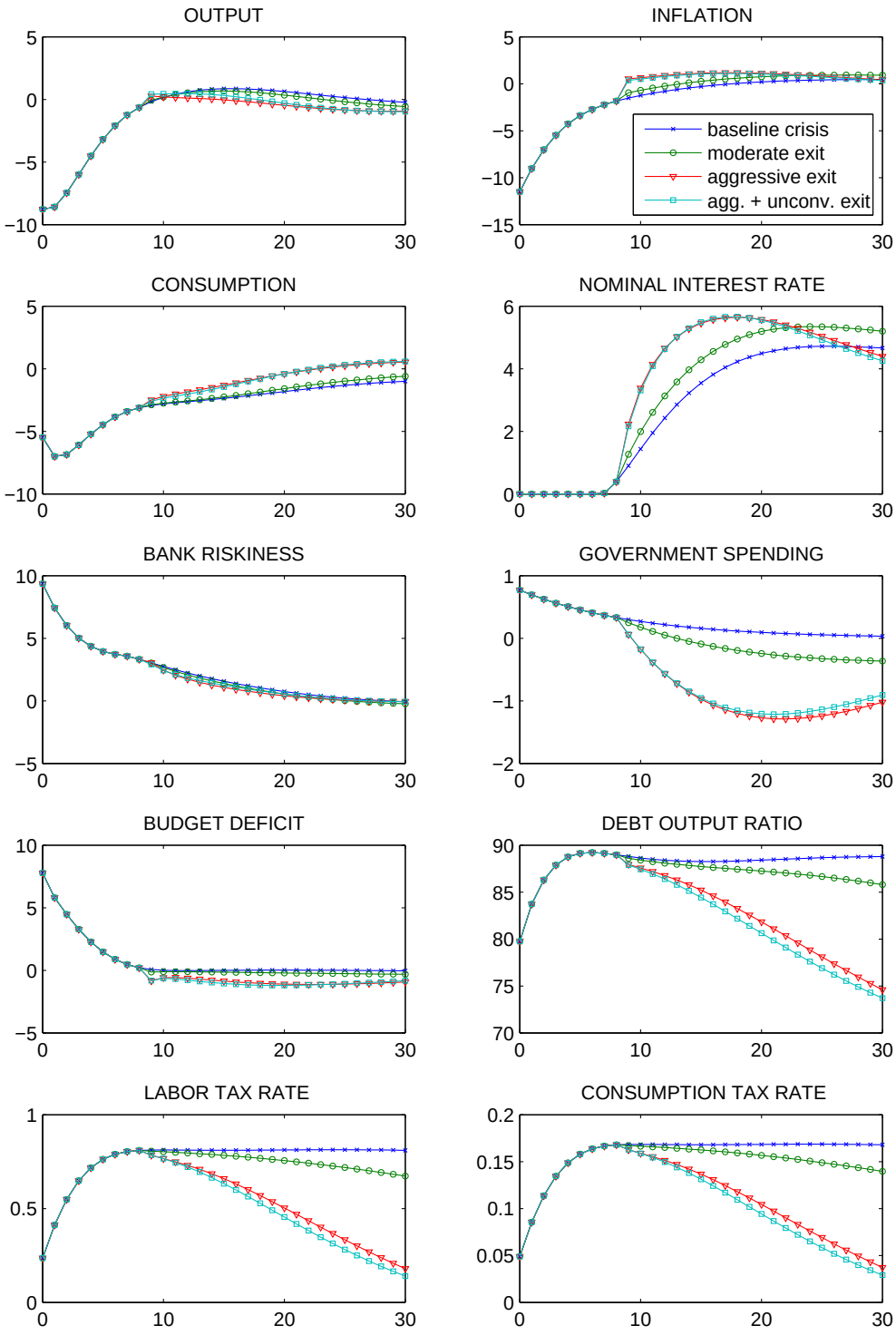


Figure 2: Unannounced moderate and aggressive expenditure-based conventional exit versus exit from both conventional and unconventional fiscal policies

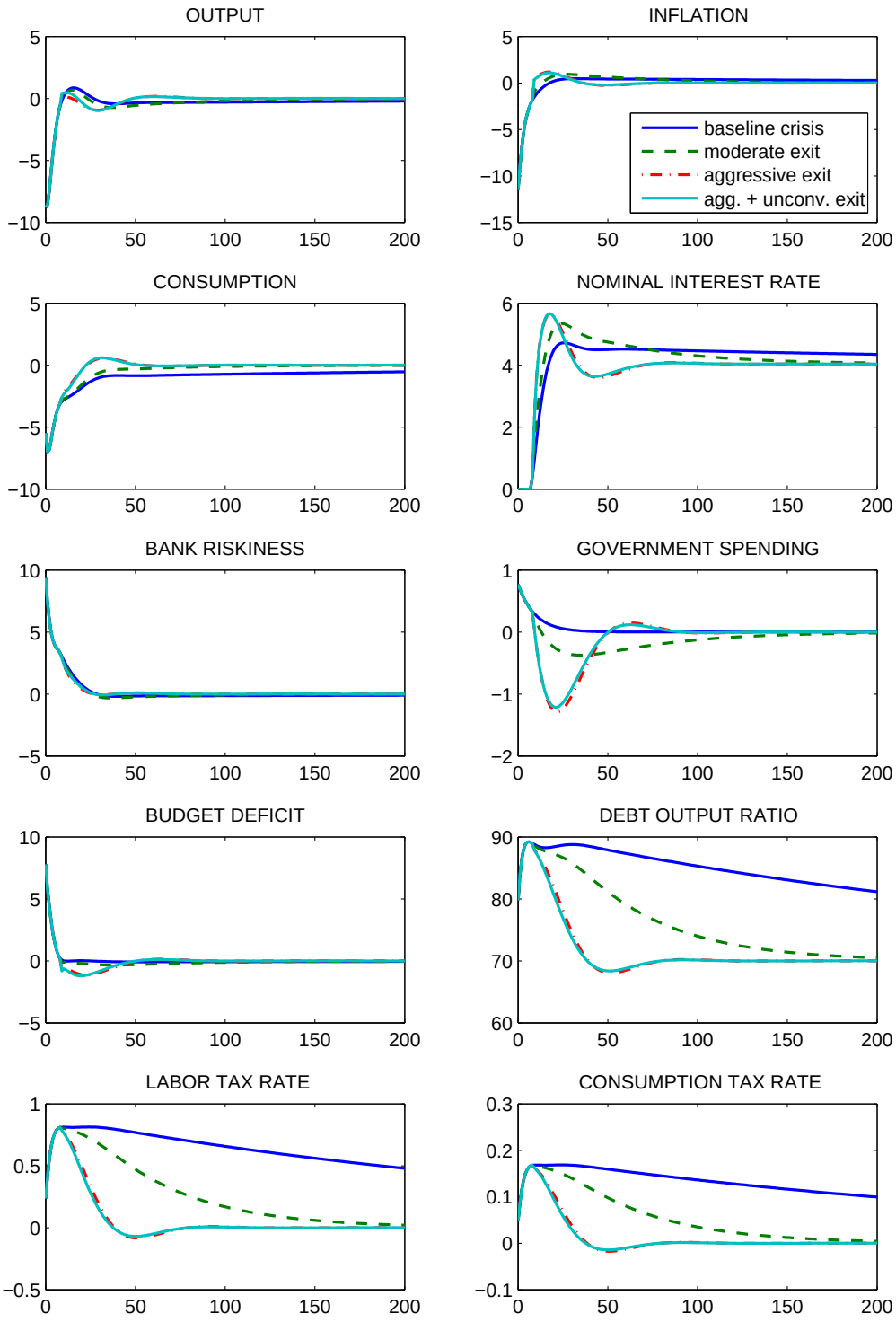


Figure 3: Unannounced moderate and aggressive expenditure-based conventional exit versus exit from both conventional and unconventional fiscal policies

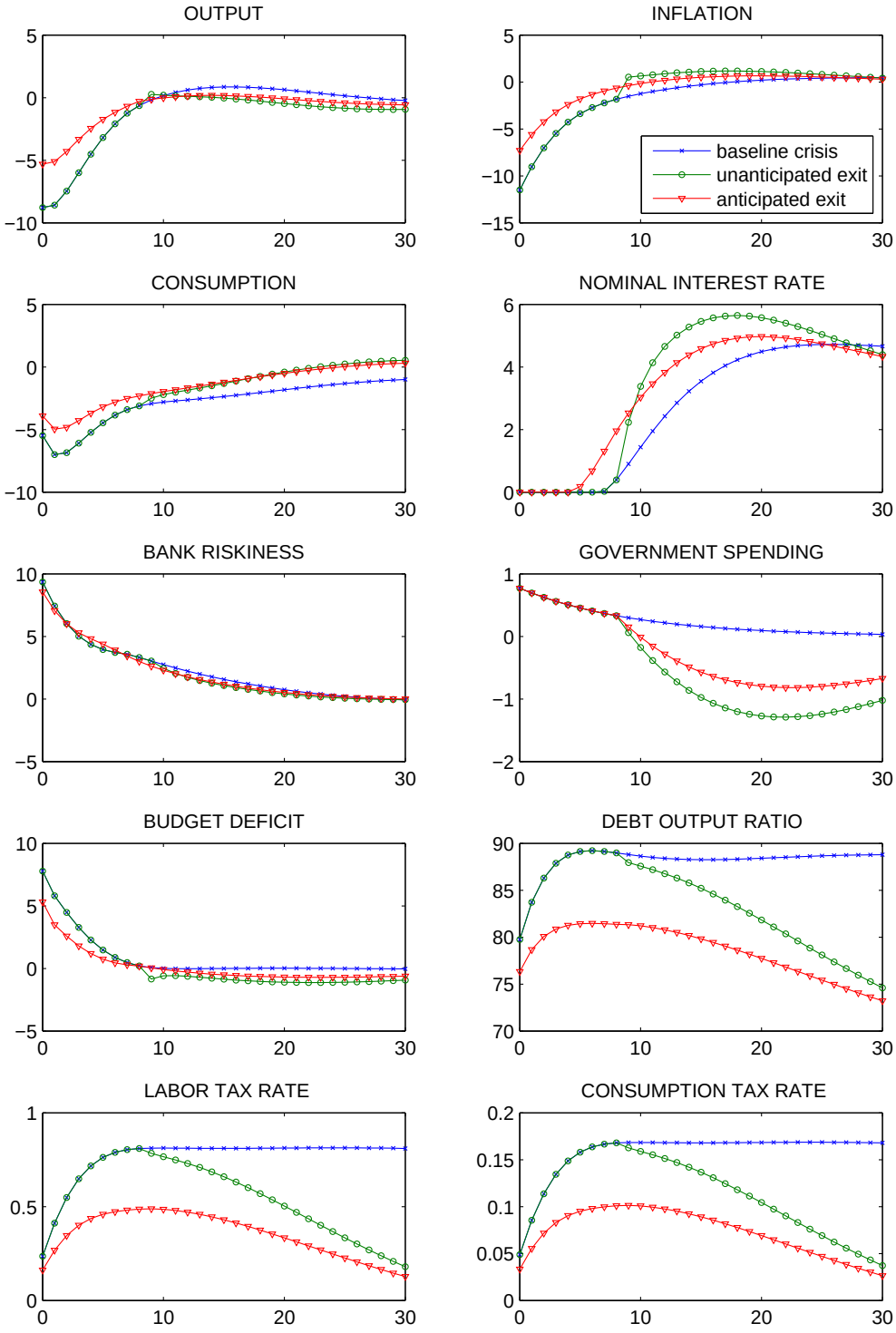


Figure 4: Announced versus unannounced spending-based aggressive strategy

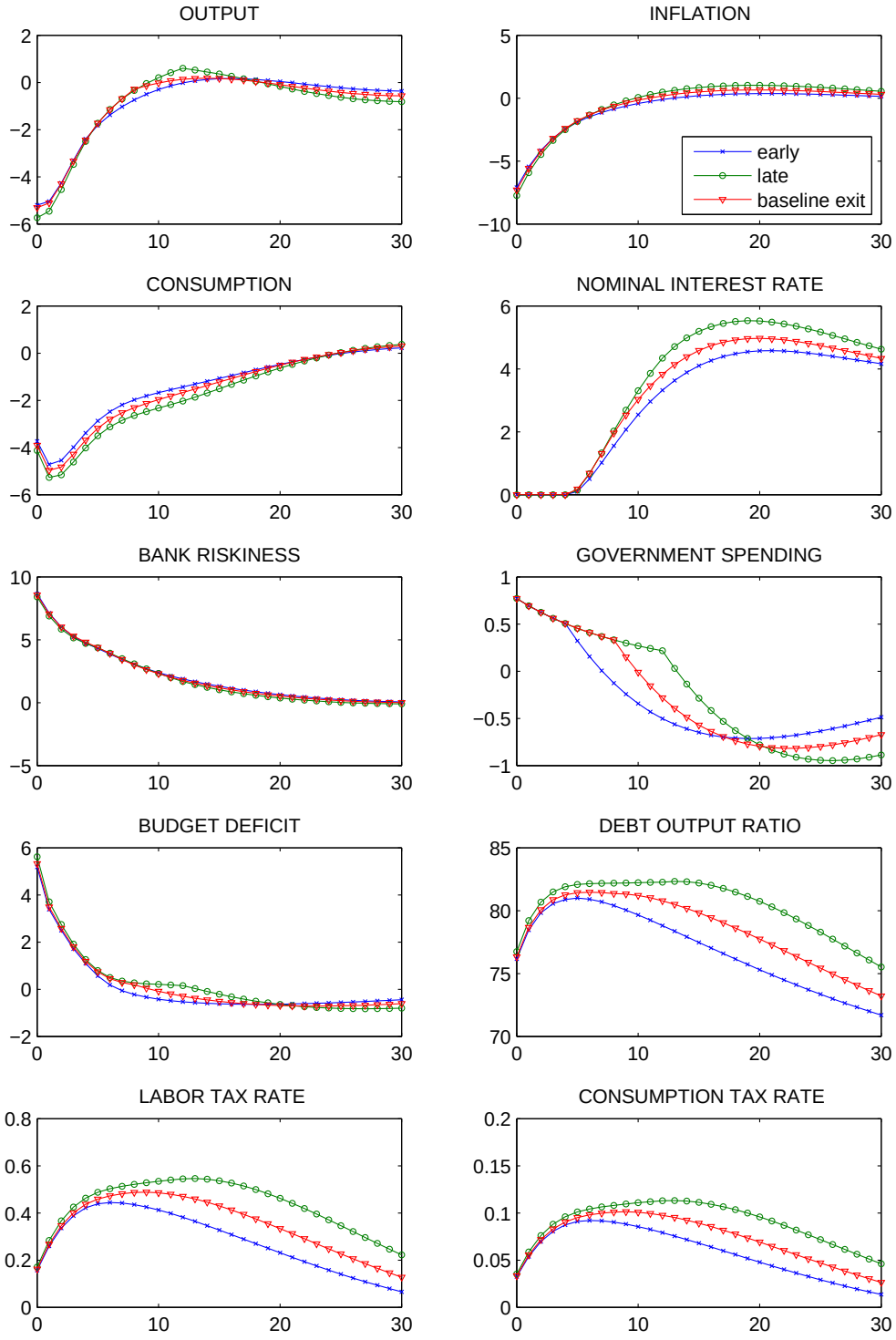


Figure 5: Announced spending-based aggressive strategy, early versus late fiscal exit

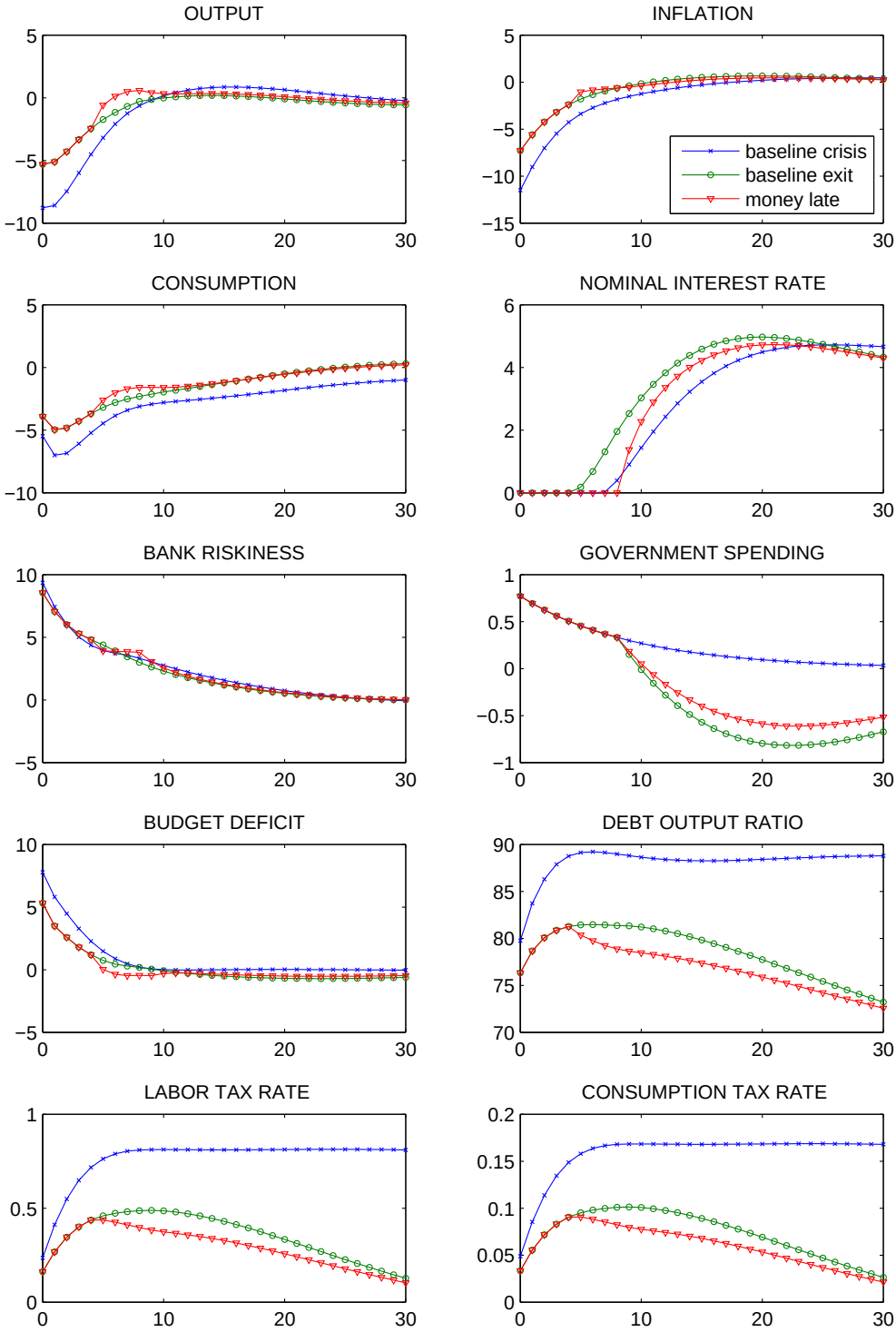


Figure 6: Announced spending-based aggressive strategy, late monetary exit

Table 1: MATCHING THE CRISIS

	Euro area				US				Model: years after shock	
	2007	**2008**	**2009**	**2010**	**2007**	**2008**	**2009**	**2010**	**1**	**2**
GDP	3,0	0,3	-4,4	1,9	1,9	-0,3	-3,1	2,4	-7,7	-2,8
Output Gap	3,5	2,2	-3,2	-2,2	2,9	0,5	-4,2	-3,4	-7,7	-2,8
Personal consumption	1,6	0,4	-0,9	1,0	2,3	-0,6	-1,9	1,8	-6,4	-4,2
Total investment	5,1	-1,6	-12,7	-0,5	-1,4	-5,1	-15,3	-0,3	-11,6	-10,3
Employment	1,8	0,9	-1,8	-0,4	1,1	-0,5	-3,8	-0,6	-4,6	-1,6
Inflat. (peak-to-through)	5,6	6,7	-2,7	-0,6	7,9	9,1	-2,0	0,4	-11,5	-4,3
Public debt/GDP	72,3	77,6	88,3	93,5	66,3	75,3	88,8	98,0	84,4	89,1
Public deficit/GDP	0,7	2,1	6,4	6,2	2,9	6,6	11,9	11,4	5,3	1,3

Source: OECD Economic Outlook 93 (June 2013) or national sources. Percentage changes relative to previous year, except when otherwise indicated. Inflation (peak-to-through) shows maximum values of the quarterly annualized inflation rate in 2007 and 2008, and minimum values in 2009 and 2010.

Table 2: COMPARISON OF ALTERNATIVE EXIT STRATEGIES

Horizon				20 quarters			All quarters				Exit from ZLB /
Criterion				Output	Bank risk	Inflation	Output	Bank risk	Inflation	Welfare	Fiscal exit
Baseline crisis scenario				-35,83	17,55	18,41	-55,26	17,63	18,70	-956,38	7 / 0
n.	Exit strategy:			Gain/loss in percent			Gain/loss in percent				Quarter
1	Baseline exit scenario	Unanticipated, moderate	Tax	-6	1	0	6	1	-1	0,02	7 / 9
2			Spending	-3	1	0	-5	1	-1	0,51	7 / 9
3		Unanticipated, aggressive	Tax	-8	3	-3	32	3	-2	0,14	7 / 9
4			Spending	-16	2	-1	5	2	0	0,78	7 / 9
5		Unanticipated, moderate	Cons. tax	-5	0	0	11	0	1	0,04	7 / 9
6			Labor tax	-8	2	0	8	2	-2	0,03	7 / 9
7		Unanticipated, aggressive	Cons. tax	-33	0	0	15	0	2	0,04	7 / 9
8			Labor tax	-2	3	-4	38	4	-3	0,18	7 / 9
9		Announced, moderate	Tax	-8	5	4	3	5	3	-0,02	7 / 9
10			Spending	15	2	15	13	2	14	0,45	7 / 9
11		Announced, aggressive	Tax	19	9	34	49	9	34	-0,02	4 / 9
12			Spending	35	4	39	47	4	40	0,54	5 / 9
13		Announced, moderate	Cons. tax	29	0	23	40	1	24	0,08	6 / 9
14			Labor tax	-15	8	4	2	8	2	-0,05	6 / 9
15		Announced, aggressive	Cons. tax	22	-1	31	52	-1	32	0,12	6 / 9
16			Labor tax	24	8	36	55	8	36	-0,04	4 / 9
17	Early fiscal exit	Unanticipated, moderate	Tax	-6	1	3	9	1	2	0,02	6 / 5
18			Spending	-4	1	2	-3	1	1	0,52	7 / 5
19		Unanticipated, aggressive	Tax	-5	4	4	36	4	5	0,14	5 / 5
20			Spending	-22	2	4	9	3	5	0,79	5 / 5
21		Announced, moderate	Tax	9	3	18	21	4	17	0,01	6 / 5
22			Spending	15	2	17	16	2	16	0,46	7 / 5
23		Announced, aggressive	Tax	36	2	51	63	2	51	0,06	4 / 5
24			Spending	31	3	40	49	4	41	0,55	5 / 5
25	Late fiscal exit	Unanticipated, moderate	Tax	-3	0	0	5	0	-2	0,02	7 / 13
26			Spending	-1	0	0	-5	0	-2	0,48	7 / 13
27		Unanticipated, aggressive	Tax	-4	1	-6	31	2	-5	0,14	7 / 13
28			Spending	-6	1	-2	5	1	-2	0,74	7 / 13
29		Announced, moderate	Tax	-30	4	-12	-21	4	-14	-0,05	7 / 13
30			Spending	12	2	12	8	2	10	0,44	7 / 13
31		Announced, aggressive	Tax	-24	21	-4	12	21	-4	-0,07	5 / 13
32			Spending	37	6	35	41	6	35	0,55	5 / 13
33	Late monetary exit	Unanticipated, moderate	Tax	12	-1	1	23	-1	1	0,03	11 / 9
34			Spending	13	-1	1	12	-1	1	0,44	11 / 9
35		Unanticipated, aggressive	Tax	24	-1	-1	53	-1	0	0,12	11 / 9
36			Spending	8	-1	1	26	0	2	0,64	11 / 9
37		Announced, moderate	Tax	18	2	5	27	3	5	-0,01	11 / 9
38			Spending	35	1	16	33	1	16	0,37	11 / 9
39		Announced, aggressive	Tax	42	7	37	65	8	38	-0,01	8 / 9
40			Spending	53	2	40	62	3	41	0,44	9 / 9
41	Exit from bank support policy	Unanticipated, moderate	Tax	1	1	0	14	1	0	-0,01	7 / 9
42			Spending	3	1	0	3	1	0	0,44	7 / 9
43		Unanticipated, aggressive	Tax	3	2	-2	40	3	-1	0,12	7 / 9
44			Spending	-8	2	0	10	2	1	0,71	7 / 9
45		Announced, moderate	Tax	-7	5	2	7	5	2	-0,04	7 / 9
46			Spending	14	2	12	14	2	11	0,42	7 / 9
47		Announced, aggressive	Tax	27	9	34	55	9	35	-0,02	5 / 9
48			Spending	37	4	37	47	4	37	0,52	5 / 9

Gains (+) or losses (-), in percent, of the corresponding exit strategy in terms of the given criterion, relative to the no exit scenario. The values for the no exit scenario are calculated relative to the steady state. For output the criterion is the discounted present value of the future values of the corresponding variable. For bank risk and inflation the criterion is the root discounted square deviation. The dark green cells denote a gain of more than 20 percent, the light green cells denote a gain of more than 1 percent. The dark red cells denote a loss of more than 20 percent. The light red cells denote a loss of more than 1 percent.

Table 3a: FISCAL MULTIPLIERS (ALL QUARTERS) (*)

Model:			Banking	No banking	*Difference*
Fiscal policy rule:	Taxes	Baseline	-0,01	-0,70	*0,69*
		Aggressive	0,94	0,54	*0,40*
		Aggressive- Baseline	*0,96*	*1,25*	*-0,29*
	Spending	Baseline	-0,01	-0,70	*0,69*
		Aggressive	1,90	1,50	*0,40*
		Aggressive-Baseline	*1,91*	*2,20*	*-0,29*

(*) Ratio of net present value of output changes to net present value of spending changes, following a spending shock.

Table 3b: FISCAL MULTIPLIERS (20 QUARTERS) (*)

Model:			Banking	No banking	*Difference*
Fiscal policy rule:	Taxes	Baseline	0,78	0,64	*0,13*
		Aggressive	1,15	0,58	*0,57*
		Aggressive-Baseline	*0,37*	*-0,07*	*0,44*
	Spending	Baseline	0,78	0,64	*0,14*
		Aggressive	1,59	1,15	*0,44*
		Aggressive-Baseline	*0,81*	*0,51*	*0,30*

(*) Ratio of net present value of output changes to net present value of spending changes, following a spending shock.

Table 4: COMPARISON OF ALTERNATIVE EXIT STRATEGIES (NO-ZLB)

Horizon				20 quarters			All quarters			
Criterion				Output	Bank risk	Inflation	Output	Bank risk	Inflation	Welfare
Baseline crisis scenario				-11,07	16,15	9,19	-16,51	16,20	9,28	-956,10
n.	Exit strategy:			Gain/loss in percent			Gain/loss in percent			
1	Baseline exit scenario	Unanticipated, moderate	Tax	-5	0	0	11	0	0	0,01
2			Spending	-2	0	0	-4	0	0	0,21
3		Unanticipated, aggressive	Tax	-6	0	-1	44	0	0	0,05
4			Spending	-21	0	0	5	0	1	0,32
5		Unanticipated, moderate	Cons. tax	-8	0	0	14	0	1	0,01
6			Labor tax	-5	0	0	17	0	0	0,01
7		Unanticipated, aggressive	Cons. tax	-51	0	0	16	0	1	0,01
8			Labor tax	0	0	-1	51	0	0	0,06
9		Announced, moderate	Tax	-12	2	4	3	2	4	-0,01
10			Spending	0	1	6	-3	1	6	0,20
11		Announced, aggressive	Tax	-37	6	13	18	6	14	-0,02
12			Spending	-15	2	17	7	2	17	0,32
13		Announced, moderate	Cons. tax	3	0	8	24	0	8	0,02
14			Labor tax	-20	3	4	1	3	4	-0,01
15		Announced, aggressive	Cons. tax	-33	-1	10	29	-1	11	0,04
16			Labor tax	-40	7	13	20	7	14	-0,04
17	Early fiscal exit	Unanticipated, moderate	Tax	-8	0	2	12	1	2	0,01
18			Spending	-7	0	1	-4	1	1	0,22
19		Unanticipated, aggressive	Tax	-7	0	3	48	0	4	0,06
20			Spending	-39	1	3	5	1	3	0,33
21		Announced, moderate	Tax	-14	1	8	7	1	8	0,00
22			Spending	-4	1	7	-2	1	7	0,22
23		Announced, aggressive	Tax	-32	1	27	30	1	28	0,00
24			Spending	-33	2	17	8	2	18	0,34
25	Late fiscal exit	Unanticipated, moderate	Tax	-1	0	0	10	0	0	0,01
26			Spending	1	0	0	-4	0	0	0,19
27		Unanticipated, aggressive	Tax	1	0	-2	40	0	-1	0,05
28			Spending	-5	0	0	5	0	0	0,30
29		Announced, moderate	Tax	-15	1	-1	-5	2	-1	0,00
30			Spending	3	1	6	-4	1	5	0,19
31		Announced, aggressive	Tax	-38	8	2	3	8	3	-0,01
32			Spending	1	3	15	4	3	15	0,31
33	Exit from bank support policy	Unanticipated, moderate	Tax	2	0	0	18	0	1	0,00
34			Spending	4	0	0	3	0	0	0,19
35		Unanticipated, aggressive	Tax	2	0	0	50	0	1	0,05
36			Spending	-15	0	0	9	0	1	0,30
37		Announced, moderate	Tax	-9	2	3	8	2	3	-0,01
38			Spending	3	1	6	2	1	6	0,19
39		Announced, aggressive	Tax	-30	6	13	25	6	13	-0,03
40			Spending	-12	2	16	10	2	17	0,31

Gains (+) or losses (-), in percent, of the corresponding exit strategy in terms of the given criterion, relative to the baseline crisis scenario. The values for the baseline crisis scenario are calculated relative to the steady state. For output the criterion is the discounted present value of the future values of the corresponding variable. For bank risk and inflation the criterion is the root discounted square deviation. The dark green cells denote a gain of more than 20 percent, the light green cells denote a gain of more than 1 percent. The dark red cells denote a loss of more than 20 percent. The light red cells denote a loss of more than 1 percent. The welfare gain/loss is calculated as the fraction of consumption that would be needed to equate conditional welfare under the baseline crisis scenario (reported on top of the table) to the level of welfare implied by the corresponding exit strategy. The dark green cells denote a gain of more than 0.2 percent, the light green cells denote a gain of more than 0.01 percent. The light red cells denote a loss of more than 0.01 percent.

Table 5a: FISCAL MULTIPLIERS, NO-ZLB (ALL QUARTERS) (*)

Model:			Banking	No banking	*Difference*
Fiscal policy rule:	Taxes	Baseline	0,02	-1,07	*1,09*
		Aggressive	0,30	-0,72	*1,02*
		Aggressive-Baseline	*0,28*	*0,35*	*-0,07*
	Spending	Baseline	0,02	-1,07	*1,09*
		Aggressive	0,50	-0,32	*0,82*
		Aggressive-Baseline	*0,48*	*0,75*	*-0,28*

(*) Ratio of net present value of output changes to net present value of spending changes, following a spending shock.

Table 5b: FISCAL MULTIPLIERS, NO-ZLB (20 QUARTERS) (*)

Model:			Banking	No banking	*Difference*
Fiscal policy rule:	Taxes	Baseline	0,80	0,39	*0,41*
		Aggressive	0,51	-0,99	*1,50*
		Aggressive-Baseline	*-0,30*	*-1,38*	*1,08*
	Spending	Baseline	0,80	0,39	*0,41*
		Aggressive	0,96	0,18	*0,78*
		Aggressive-Baseline	*0,16*	*-0,21*	*0,37*

(*) Ratio of net present value of output changes to net present value of spending changes, following a spending shock.

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