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May 2016

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Fiscal Consolidation Under Imperfect Credibility*

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Sveriges Riksbank Working Paper Series
No. 322
May 2016

Abstract

This paper examines the effects of expenditure-based fiscal consolidation when credibility as to whether the cuts will be long-lasting is imperfect. We contrast the impact limited credibility has when the consolidating country has the means to tailor monetary policy to its own needs, with the impact when the country is a small member of a currency union with a negligible effect on interest rates and on nominal exchange rates of the currency union. We find two key results. First, in the case of an independent monetary policy, the adverse impact of limited credibility is relatively small, and consolidation can be expected to reduce government debt at a relatively low output cost given that monetary policy provides more accommodation than it would under perfect credibility. Second, the lack of monetary accommodation under currency union membership implies that the output cost may be significantly larger, and that progress in reducing government debt in the short and medium term may be limited under imperfect credibility.

JEL Classification: E32, F41

Keywords: Monetary and Fiscal Policy, Front-Loaded vs. Gradual Consolidation, DSGE Model, Sticky Prices and Wages, Currency Union.

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*We are grateful for the useful comments provided by the editors, an anonymous referee, our discussant Werner Roeger and other participants at the EC workshop on "Expenditure-based consolidations: experiences and outcomes" in Brussels on 20 January 2015, our discussant Josef Hollmayr at the T2M conference at Humboldt University in March 2015, and our discussant Rigas Oikonomou at the "Post-Crisis Slump" conference in October 2015. Comments by participants at the EEA 2015 conference in Mannheim, and at seminars at the Bank of Canada, Bank of Spain, and the GSMG in Stockholm were also helpful. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Banque de France, the Sveriges Riksbank or any other person associated with these institutions. Email addresses: jesper.linde@riksbank.se and matthieu.lemoine@banque-france.fr

1 Introduction

The global financial crisis and ensuing slow recovery have put severe strains on the fiscal positions of many industrial countries, especially those of many peripheral economies in the euro area. Between 2007 and 2014, debt/GDP ratios climbed considerably in many euro area countries, including the peripheral countries shown in Figure 1, with debt rising by 61 percent of GDP in Spain and by as much as 74 percent of GDP in Greece. Mounting concern about high and rising debt levels, especially in the wake of the rise in borrowing costs, spurred efforts to implement sizeable fiscal consolidation plans. So far, many of the fiscal consolidation plans that have received legislative approval in the peripheral euro area economies appear to have shared broadly similar features – they have typically been fairly front-loaded and more oriented towards spending cuts than tax hikes (see IMF, 2012, and European Commission, 2014).

However, despite significant consolidation efforts, the debt ratios of peripheral economies have not improved much, as can be seen in Figure 1, although deflation has largely been avoided (except in Greece - see bottom left panel in Figure 1). The only exception is Ireland, where the debt/GDP ratio fell almost 13 percentage points between 2012 and 2014, mainly due to a snapback in economic activity as shown in the top right-hand panel in Figure 1. In all other countries, output performance has been subpar to core countries and debt has continued to rise or has remained roughly unchanged. Hence, the evolution of debt and output during this period does not seem to support the popular policy recipe – notably advocated by Alesina and Ardagna (2010), Alesina and Perotti (1995, 1997) and Giavazzi and Pagano (1990) – that large spending-based fiscal consolidations have expansionary effects on the economy. Ireland may offer a counterexample, but the evolution of unit labour costs shown in the bottom right-hand panel in Figure 1 suggests that the favourable performance of Ireland may partly be due to an internal devaluation as opposed to the expansionary effects of fiscal consolidation.

In this paper, we seek to analyze the impact that imperfect commitment to following through on the announced consolidation efforts has on the output cost of fiscal austerity and on the effectiveness in reducing debt/GDP ratios in the short and medium term. Given the sizeable consolidation plans, we believe that economic actors – both households and investors – may have had considerable doubts about the ability of politicians to follow through on their implementation, and we seek to understand how these doubts may have affected their efficiency. Our paper makes a purely positive examination of this issue by, first, assessing whether imperfect credibility is empirically important, and second, by investigating how the economic impact of expenditure-based consolidation depends on the degree of credibility that the spending cut will be permanent and not transient.

To examine the first issue, we decompose data on government spending (as a share of trend output) into permanent and temporary components for a selected set of peripheral euro area economies.[1] Our simple decomposition supports the notion that credibility is imperfect for some of these economies; in particular, we find that credibility for permanent spending cuts is impaired for Greece.

Given this finding, we then address the second issue, which is to quantify the economic impact of imperfect fiscal credibility in two variants of a dynamic stochastic general equilibrium model (henceforth a DSGE) of an open economy. We start our analysis using the analytically tractable benchmark model of Clarida, Galí and Gertler (2001), and then check the robustness of our findings in a fully-fledged workhorse open economy model used by Erceg and Lindé (2010, 2013). Following Erceg, Guerrieri and Gust (2006), this model features "rule-of-thumb" households that simply consume their disposable income every period, as ample micro and macro evidence suggests that such non-Ricardian consumption behavior is a key transmission channel for fiscal policy.[2] In other respects, the model is a relatively standard two-country open economy model with endogenous capital formation, which embeds the nominal and real frictions that have been identified as empirically important in the closed economy models of Christiano, Eichenbaum and Evans (2005) and of Smets and Wouters (2003), as well as analogous frictions relevant in an open economy framework (such as costs of adjusting trade flows). Given the importance of financial frictions as an amplification

[1] To provide a point of comparison for our procedure, we also perform the decomposition for Germany and the United States.

[2] Using micro data from the Consumer Expenditure Survey, Johnson et al. (2006) and Parker et al. (2011) find evidence of a substantial response of US household spending to the temporary tax rebates of 2001 and 2008. On the macro side, Galí, López-Salio and Vallés (2007) present evidence from structural VARs that government spending shocks tend to boost private consumption, and show how the inclusion of rule-of-thumb agents in their DSGE model helps it account for this behaviour. Blanchard and Perotti (2002), and Monacelli and Perotti (2008) obtain similar empirical findings.

mechanism – as highlighted by the recent work of Christiano, Motto and Rostagno (2010) – the model also incorporates a financial sector following the basic approach of Bernanke, Gertler and Gilchrist (1999).

To begin with, we assume that the consolidating economy has the means to pursue an independent monetary policy (henceforth IMP), defined here as the ability for the central bank to tailor nominal interest rates (and hence the exchange rate) in order to stabilize inflation around target and stabilize output around its efficient level. After considering IMP as a useful reference point, we then move on to the benchmark case in which the consolidating economy is a small member of a currency union (henceforth CU), without the means to exert any meaningful influence on currency union policy rates and on its nominal exchange rate. The latter case, we believe, is the most interesting one given the prevailing situation for many European peripheral economies.

Our main findings are as follows. First, under IMP, the adverse impact of limited credibility is relatively small, and consolidation can still be expected to reduce government debt at a relatively low output cost given that monetary policy provides more accommodation than it would under perfect credibility. Second, the lack of monetary accommodation under CU membership implies that the output cost may be significantly larger under imperfect credibility, suggesting that progress in reducing government debt in the short and medium term is limited when the consolidation is implemented quickly. For a small CU member, a gradual approach to consolidation has the dual benefit of mitigating the need for monetary accommodation and building credibility over the permanence of the cuts more quickly. While the benefit of acting gradually due to the reduced need for monetary accommodation has been pointed out previously by Corsetti, Meier and Müller (2012) and by Erceg and Lindé (2013), we show that imperfect credibility is an additional argument as to why it might be preferable to adopt a gradual approach.

After establishing these preliminary results in the stylized model, we conduct a more serious quantitative analysis using the fully-fledged model of Erceg and Lindé (2013), in which we allow interest rate spreads in the periphery to respond endogenously to the path of expected debt and deficits. In this model, we first show that the basic findings of the stylized model hold up surprisingly well. Next, we show that fiscal consolidation may in fact be expansionary if the government enjoys a sufficiently high degree of credibility. Even so, the favourable results under endogenous spreads are sensitive to the way in which the consolidation is implemented. In particular, if the government pursues an overly ambitious spending-based consolidation programme that seeks to reduce the debt/GDP ratio in the short run through aggressive spending cuts, there is a risk that it will remove too much demand from the economy, which could prove counter-productive for the debt/GDP ratio in the short- and medium-term. Thus, our model results suggest that the aggressive austerity measures implemented in many peripheral economies, and perhaps most notably in Greece, were most likely not expansionary, in line with the conclusions by Bi, Leeper and Leith (2013). Thus, echoing the benefits of acting gradually in the stylized model, a more effective route for reducing debt quickly at low output cost in the fully-fledged model is to implement spending cuts gradually and then wait patiently until private demand is crowded in and debt starts falling. An empirical paper by Born et al. (2015) provides estimates of a panel VAR using a dataset of 26 emerging and advanced economies regarding the interaction of fiscal consolidation and interest rate spreads. Consistent with the findings of our workhorse model, it shows that a cut in government consumption that is perceived to be temporary can induce a short-term rise in spreads, whereas a permanent spending cut leads to a fall in spreads.

Perhaps somewhat surprisingly, relatively few papers have analyzed the role imperfect credibility might play in shaping the effects of fiscal consolidations in a DSGE framework. One exception is Bi, Leeper and Leith (2013) who explore the macroeconomic consequences of fiscal consolidations with uncertain timing and composition (tax vs. spending). They argue that the conditions that could render fiscal consolidation efforts expansionary are unlikely to apply in the current economic environment. Some prominent policy institutions have also analyzed this issue. First, Clinton et al. (2011) show with the GIMF model that credibility plays a crucial role in determining the size of output losses, by analyzing sensitivity of these losses to the length of an initial period without credibility. Focusing on spillover issues, in't Veld (2013) uses as a benchmark scenario a multi-year consolidation with gradual learning, i.e. where austerity measures are considered as temporary in a learning period and are expected to be permanent only after this learning period. He shows that, in the short run, output losses would be considerably smaller if consolidations gained credibility earlier. Simulations of consolidations with the ECB's NAWM model also deliver larger multipliers in the case of "imperfect credibility" (modeled in the same way with a learning period where fiscal shocks are initially perceived as temporary, see Box 6 of ECB, 2012). A key difference between our approach and the one adopted by these papers is that the degree of credibility in our set-up is *endogenous* as it depends on the path of government spending and is not assumed exogenous, with government spending driven by unexpected shocks for a fixed number of quarters.

The reminder of the paper is organized as follows. The next section assess the empirical relevance of imperfect credibility. Section 3 presents the simple benchmark model, discusses its calibration, and examines the role imperfect credibility plays in this stylized model under monetary independence and currency union membership. In Section 4, we then examine the robustness of the results for the stylized model in the large-scale model with hand-to-mouth households and financial frictions. Finally, Section 5 concludes.

2 An Empirical Assessment of Credibility

In this section, we attempt to decompose government spending into permanent and temporary components. This empirical study will be useful for assessing the influence of imperfect credibility. Indeed, as we will show in quantitative simulations of the paper, the larger the weight of the permanent component – relative to the temporary one– the easier it is to extract this permanent component and the faster a permanent consolidation of government spending will become fully credible.

We focus on some countries of the euro area periphery: Ireland, Italy, Portugal, Spain, and Greece. We also add Germany and the United States as benchmarks. Within the analysis we use OECD national accounts quarterly series for "Government final consumption expenditures" and GDP, in constant prices over the period 1980Q1–2008Q4. Using this data we measure government spending as a ratio of government consumption over (lagged) trend output following Gali et al. (2007).[3] We believe that 1980 is a good initial point for the

[3] We compute trend output by using a HP filter with a smoothing parameter $\lambda = 1600$. We also have

estimations since the 1960s and 1970s was a period characterized by an expanding welfare state in many European countries, which obviously had nothing to do with consolidations. The sample was also chosen to end 2008Q4 in order to avoid obtaining results influenced by the specific evolution of post-crisis government spending. The data we use is plotted in Figure 2 (blue solid line).

The starting point in our empirical analysis is that total government spending (as share of lagged trend output) g_t, is the sum of a permanent- and one transient shock (denoted g_t^{perm} and g_t^{temp} respectively), which are assumed to be given by the following processes:

$$g_t - \bar{g} = (g_t^{perm} - \bar{g}) + g_t^{temp} \tag{1}$$

$$\Delta \left(g_t^{perm} - \bar{g}\right) = \rho_1^{perm} \Delta \left(g_{t-1}^{perm} - \bar{g}\right) - \rho_2^{perm} (g_{t-1}^{perm} - \bar{g}) + \frac{1}{g_y} \varepsilon_t^{perm} \tag{2}$$

$$g_t^{temp} = \rho^{temp} g_{t-1}^{temp} + \frac{1}{g_y} \varepsilon_t^{temp}, \tag{3}$$

where the standard errors of the shocks ε_t^{perm} and ε_t^{temp} are given by σ_{perm} and σ_{temp} respectively. By assuming that the permanent component follows an AR(2)-process with positive persistence in growth rates ($\rho_1^{perm} > 0$) and slow mean reversion back to steady state $\bar{g}$ (ρ_2^{perm} is assumed to be very small), we ensure that the permanent component in Equation (2) will be a smooth process. The temporary component shown in Equation (3) , on the other hand, is assumed to be a simple AR(1) process and may thus be characterized by transient fluctuations when ρ^{temp} is relatively small and σ_{temp} is high.

We estimate the parameters in Equations (2)–(3) by likelihood based methods, but since some of the parameters are weakly identified as we only match one time series (g_t), we impose strict priors for some of the parameters. To begin with, we assume that $\rho_1^{perm} = 0.9$, and $\rho_2^{perm} = 0.005$.[4] As discussed previously, this ensures that the permanent component is fairly smooth. We also assume that $\rho^{temp} = 0.8$. This value is reasonable because it enables our estimated model, which features both permanent and transient shocks according to Equation (1), to reproduce the persistence of government spending shocks normally found

examined that our results are robust when setting the smoothness parameter to 6400, which is the upper value of λ proposed by Hodrick and Prescott (1997). A higher λ provides a smoother trend output series.

[4] For Portugal, however, we set $\rho_1^{perm} = 0.7$ and impose a ratio between $\sigma_{perm}/\sigma_{temp}$ estimated on annual data to obtain convergence in the estimation on quarterly data. This estimation problem for Portugal at the quarterly frequency seems to be related to the smoothness of this time series within each year, perhaps due to interpolation procedures used to construct quarterly national accounts.

in the business cycle literature.[5] Moreover, the data does not speak much against our chosen values of ρ_1^{perm}, ρ_2^{perm}, and ρ^{temp}; conditional on $\rho_2^{perm} = 0.005$, varying ρ_1^{perm} and ρ^{temp} between 0.6 and 0.95 only results in a significant difference in the likelihood at the 5-percent level relative to our chosen parameterization for Spain according to a simple Likelihood ratio test.[6] Consequently, we believe that our choice of parameters is reasonable from an economic viewpoint, and generally supported by data. Even so, we acknowledge that the exact details of the estimation results are somewhat sensitive to these choices, but want to stress that the overall message is not much affected, as discussed in further detail below.

Table 1: Estimated standard deviations of shocks for government spending process.

	Country						
Parameter	Ireland	Italy	Portugal	Spain	Greece	Germany	United States
σ_{perm}	0.118	0.031	0.021	0.035	0.019	0.026	0.040
σ_{temp}	0.184	0.127	0.116	0.141	0.260	0.157	0.129
SNR	0.645	0.247	0.185	0.246	0.072	0.164	0.314

Note: The estimates reported are conditional on $\rho_1^{perm} = 0.9, \rho_2^{perm} = 0.005$, and $\rho^{temp} = 0.8$. For Portugal we use $\rho_1^{perm} = 0.7$. The SNR is defined in Equation (4).

In Table 1 we report the estimation results in terms of standard deviations for the permanent and transient shocks, as well as the implied signal to noise ratio of innovations (SNR henceforth), defined as

$$SNR = \frac{\sigma_{perm}}{\sigma_{temp}}. \tag{4}$$

One can observe that Greece has the lowest SNR-ratio ratio at 0.07, while the other countries' ranges from 0.164 (Germany) to 0.65 (Ireland). United States obtains a reasonably high value of 0.31. The fact that Greece has the lowest SNR is perhaps not too surprising.

[5] In the business cycle literature (see e.g. Christiano and Eichenbaum, 1992) the persistence of government spending shocks – often defined as the first-order auto-correlation coefficient of linearly detrended government spending – ranges around 0.95 for the United States. We find that the median correlation generated by our state-space model for the various countries is well in line with this evidence. We verify this by simulating 5,000 artificial samples of the same length as in the data from our state-space model as well as trend output from a random walk model with drift and recovering for each draw the log of linearly detrended series for government spending and estimating the corresponding moment. Specifically, we find median persistence coefficients of 0.99, 0.97, 0.95, 0.97, 0.86, and 0.94 for Ireland, Italy, Portugal, Spain, Greece, and Germany, respectively, on simulated samples, while the coefficients obtained by linearly detrending the log of observed government spending are 0.99, 0.98, 0.99, 0.97, 0.98, and 0.98. If we also compute ranges with 2.5% and 97.5% quantiles of distributions of persistence estimates, we find that observed persistence are always within these ranges, except for Greece and Portugal where observed persistence (0.98 and 0.99) are slightly higher than the upper bounds (0.95 and 0.98).

[6] Given our grid, the maximum likelihood estimates of ρ_1^{perm} and ρ^{temp} equals 0.6 and 0.75 for Spain. Because of convergence problems of the estimation algorithm on a sub-region of the space defined by these ranges, Portugal was excluded from this exercise.

More surprising is perhaps the fact that Germany has the third-lowest SNR and that Ireland is most credible according to this metric. To get a better grasp of the mechanisms at work, Figure 2 shows the two-sided smoothed permanent component along with the actual g_t series.

Observable in Figure 2 is that Ireland is characterized by very persistent movements in g_t during the sample period. Thus, according to our simple, yet straightforward, assumptions about the permanent and transient components, Ireland is estimated to have a relatively high variance of the permanent component, and thus a relatively high SNR. Germany, on the other hand, which does not have a low-frequency drift in its series, will have relatively more mass in the transient component and thereby a lower SNR. Because we do not think a country (like Germany), which manages to keep the spending ratio roughly constant for a considerable period of time, should necessarily be plagued by imperfect credibility if they indeed attempted to reduce their spending ratio, we believe this finding underscores possible limitations with our method, which is statistical in nature and does not take intangibles like the political decision process into consideration.[7]

Despite the shortcomings of our simple method, we believe it is sufficiently robust to point out that Greece is special: As can be seen from Figure 2, the Greek spending series has more high-frequency movements than the German one, and displays little signs of an upward or downward trend. Hence, it seems totally reasonable that our method classifies that country to have a low SNR. That Greece has the lowest SNR is moreover a robust finding in our estimations and is not sensitive to the strict priors we adopt for ρ_1^{perm}, ρ_2^{perm}, and ρ^{temp}. When we vary these parameters within reasonable bounds, Greece comes out with the lowest SNR in 92 percent of the draws. If anything, the smoothed permanent component in Figure 2 may be too fast-moving for all countries, and one could therefore imagine that the SNRs are even lower than those reported in Table 1.

In the following, we use the results for Spain – which are in the mid-range of the SNR-ratios – in our model simulations. This should give us reasonable assessment of how important credibility issues may be. Nevertheless, we acknowledge that our empirical results should

[7] For instance, it cannot deal with the impact of the German reunification, which is likely to have exerted an upward pull on government expenditures in Germany.

be taken with a grain of salt and that more work on refining and examining the robustness of our findings with alternative empirical strategies would be of interest.[8]

3 Imperfect Credibility in a Stylized Small Open Economy Model

We start our model from a simple stylized DSGE one. In Section 4 we examine the robustness of our results in a large scale "workhorse"model.

3.1 The Model

Our stylized model is very similar to the small open economy model of Clarida, Galí, and Gertler (2001). Households consume one domestic and one foreign good, which are imperfect substitutes to each other. The government, however, only consumes the domestic good. To rationalize Calvo-style price rigidity, the domestic good is assumed being comprised of a continuum of differentiated intermediate goods, each of which is produced by a monopolistically competitive firm. The evolution of government debt is stabilized by varying lump-sum taxes, which means that the aggressiveness of debt- and deficit-stabilization in the tax rule is irrelevant for aggregate quantities and prices as Ricardian equivalence holds in the model. The home economy is small in the sense that it does not influence any foreign variables, and financial markets are complete. To save space, we present only the log linearized model in which all variables are expressed as percent or percentage point deviations from their steady state levels, and we omit all foreign variables.

[8] Paredes et al. (2015) makes an attempt to quantify the degree of credibility for Germany, France, Italy, and Spain. Moreover, following the approach by Erceg and Levin (2003), one additional strategy could be to estimate the signal-noise ratio by minimizing the sum of squared deviations between observed data and one year-ahead expected government spending, and the corresponding inflation expectations implied by our state-space model using forecasts from OECD-economic-outlooks. A disadvantage of such an approach is that it relies heavily on the unbiasedness of the forecasts, which may be a too strong assumption.

Under an independent monetary policy, the key equations are given by Equations (5) to (11) :

$$x_t = \mathrm{E}_t x_{t+1} - \hat{\sigma}^{open}(i_t - \mathrm{E}_t \pi_{t+1} - r_t^{pot}) \tag{5}$$

$$\pi_t = \beta \mathrm{E}_t \pi_{t+1} + \kappa_x x_t \tag{6}$$

$$i_t = \gamma_\pi \pi_t + \gamma_x x_t \tag{7}$$

$$y_t = \hat{\sigma}^{open} \tau_t + g_y g_t + (1 - g_y)(1 - \omega)\nu_c \nu_t \tag{8}$$

$$y_t^{pot} = \frac{1}{\phi_{mc} \hat{\sigma}^{open}} [g_y g_t + (1 - g_y)(1 - \omega)\nu_c \nu_t] \tag{9}$$

$$\tau_t^{pot} = -\frac{1}{\hat{\sigma}^{open}} (1 - \frac{1}{\phi_{mc} \hat{\sigma}^{open}}) \, [g_y g_t + (1 - g_y)(1 - \omega)\nu_c \nu_t] \tag{10}$$

$$r_t^{pot} = \mathrm{E}_t \tau_{t+1}^{pot} - \tau_t^{pot}, \tag{11}$$

in which $\hat{\sigma}^{open} = (1 - g_y)[(1 - \nu_c)(1 - \omega)^2 \sigma + \omega(2 - \omega)\varepsilon_P]$, $\phi_{mc} = \frac{\chi}{1-\alpha} + \frac{1}{\hat{\sigma}^{open}} + \frac{\alpha}{1-\alpha}$, and the superscript '*pot*' denotes the level that would prevail under flexible prices.

As in the paper of Clarida et al., the first three equations represents the New Keynesian open economy IS-curve, the Phillips Curve, and the monetary rule respectively, and which jointly determine the output gap ($x_t = y_t - y_t^{pot}$), the price inflation (π_t),, and the nominal policy rate (i_t). Thus, the output gap x_t depends inversely on the deviation of the real interest rate ($i_t - \mathrm{E}_t \pi_{t+1}$) from the potential real interest rate r_t^{pot}, with the sensitivity parameter $\hat{\sigma}^{open}$ varying positively with the household's intertemporal elasticity of substitution in consumption σ and substitution elasticity ε_P between foreign and domestic goods (the relative weight on the latter rises with trade openness ω). The Phillips curve slope κ_x in Equation (6) is the product of parameters determining the sensitivity of inflation to marginal cost κ_{mc}, and of marginal cost to the output gap ϕ_{mc}, i.e. $\kappa_x = \kappa_{mc} \phi_{mc}$. From Equation (9), a contraction in government spending g_t (g_y is the government spending share of steady state output) or negative taste shock ν_t (ν_c is a scaling parameter) reduces potential output y_t^{pot}. Even so, both of these exogenous shocks, if negative, causes the potential terms of trade τ_t^{pot} to depreciate (a rise in τ_t^{pot} in Equation 10) because they depress the marginal utility of consumption (noting $\phi_{mc}\hat{\sigma}^{open} > 1$). If both shocks follow stationary AR(1)- processes, and hence have front-loaded effects, a reduction in government spending or negative taste shock reduces r_t^{pot}. Finally, the nominal exchange rate e_t equals $p_t + \tau_t$, where $p_t = p_{t-1} + \pi_t$.

Given that the form of the equations determining output, inflation, and interest rates, is identical to that of a closed economy (as emphasized by Clarida et al.), results from extensive closed economy analysis [e.g., Erceg and Lindé (2010a)] are directly applicable for assessing the impact of government spending shocks within this open economy framework.

We next consider how the model is modified for the CU-case (largely following the analysis of Corsetti et al., 2011). A CU-member takes the nominal exchange rate as fixed, so that the terms of trade τ_t is simply the gap between home and foreign price levels, i.e., $\tau_t = -(p_t - p_t^*) = -p_t$.[9] The home economy is assumed being small enough so that the policy rate is effectively exogenous. Given that Equation (8) implies that the output gap is proportional to the terms of trade gap, i.e.

$$x_t = \hat{\sigma}^{open}(\tau_t - \tau_t^{pot}), \tag{12}$$

the price setting equation in (6) may be expressed as a second order difference equation in the terms of trade, yielding a solution of the form

$$\tau_t = \lambda\tau_{t-1} + \kappa_x\hat{\sigma}^{open}\frac{\lambda}{1-\beta\rho\lambda}\tau_t^{pot}. \tag{13}$$

The persistence parameter $\lambda = 0.5(a - \sqrt{a^2 - 4/\beta}\ )$, where $a = (\frac{1}{\beta})(1 + \beta + \kappa_x\hat{\sigma}^{open})$, lies between 0 and unity, and ρ is the persistence of the shocks (assumed to be described by AR(1)-processes for the moment being). Equation (13) has two important implications. First, because $\lambda > 0$, a contraction in government spending – which raises τ_t^{pot} by Equation (10) – moves τ_t in the same direction, implying a depreciation. Together with Equation (8), this implies that the government spending multiplier m_t is strictly less than unity, i.e., $m_t = \frac{1}{g_y}\frac{dy_t}{dg_t} = 1 + \frac{\hat{\sigma}^{open}}{g_y}\frac{d\tau_t}{d\tau_t^{pot}}\frac{d\tau_t^{pot}}{dg_t} < 1$ (recalling that $\frac{d\tau_t^{pot}}{dg_t} < 0$). Second, as $\kappa_x\hat{\sigma}^{open}$ becomes

[9] As the real exchange rate is proportional to τ_t, we use the terms interchangeably.

very small, λ rises toward unity and the coefficient on τ_t^{pot} shrinks, implying very gradual adjustment of the terms of trade to τ_t^{pot} (and hence to a change in government spending); conversely, the terms of trade adjustment is more rapid if $\kappa_x \hat{\sigma}^{open}$ is larger. In economic terms, the terms of trade adjusts more quickly if the Phillips Curve's slope is higher (high κ_x), or if aggregate demand is relatively sensitive to the terms of trade (high $\hat{\sigma}^{open}$).

3.2 The Signal Extraction Problem

To allow for imperfect credibility, we make the standard assumption that agents in the economy have to solve a signal extraction problem to filter out permanent (*perm*) and transient (*temp*) components from observed overall government spending g_t. The processes for these variables were specified in Equations (1)–(3), and can be rewritten in the following state-space form:

$$\begin{aligned} g_t - \bar{g} &= HZ_t \\ Z_t &= FZ_{t-1} + \tfrac{1}{g_y} V_t, \end{aligned} \tag{14}$$

in which

$$\begin{aligned} Z_t &= \begin{bmatrix} g_t^{perm} - \bar{g} & g_{t-1}^{perm} - \bar{g} & g_t^{temp} \end{bmatrix}' \sim \mathrm{N}(0, Q) \\ V_t &= \begin{bmatrix} \varepsilon_t^{perm} & 0 & \varepsilon_t^{temp} \end{bmatrix}' \sim \mathrm{N}(0, Q), \end{aligned}$$

and

$$F = \begin{bmatrix} 1 + \rho_1^{perm} - \rho_2^{perm} & -\rho_1^{perm} & 0 \\ 1 & 0 & 0 \\ 0 & 0 & \rho^{temp} \end{bmatrix}$$

$$H = \begin{bmatrix} 1 & 0 & 1 \end{bmatrix}$$

$$Q = \begin{bmatrix} \sigma_{perm}^2 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & \sigma_{temp}^2 \end{bmatrix}.$$

In the full-credibility-case, private agents know the present and future path of the permanent shock. In the no-credibility-case they always believe that all shocks are temporary, regardless of the spending path. In the imperfect-credibility-case, they do not observe the shocks directly, but rather learn them through Kalman filtering. This is a standard device used in the learning literature for modeling a learning process [e.g. Evans and Honkapohja (2001)], because the algorithm is optimal for extracting a signal from a given sample in real-time [Harvey, (1989)].

In the imperfect-credibility-case, we assume that agents compute recursively filtered estimates $Z_{t|t}$ of unobserved components at date t (given information up to date t) and their variance $P_{t|t}$ through the following Kalman filter:

$$
\begin{aligned}
Z_{t|t} &= FZ_{t-1|t-1} + L_t v_t \\
P_{t|t} &= FPF' + Q - \left(FP_{t-1|t-1}F' + Q\right) H' h_{t|t-1}^{-1} H \left(FP_{t-1|t-1}F' + Q\right),
\end{aligned}
$$

where the forecast error v_t, its variance $h_{t|t-1}$, and the gain L_t of the filter is computed using

$$
\begin{aligned}
v_t &= g_t - \bar{g} - HFZ_{t-1|t-1} \\
h_{t|t-1} &= H\left(FP_{t-1|t-1}F' + Q\right) H' \\
L_t &= \left(FP_{t-1|t-1}F' + Q\right) H' h_{t|t-1}^{-1}.
\end{aligned}
$$

Within the stylized model of previous section (or the large-scale model of Section 4), we incorporate this signal extraction process by replacing the 3-dimensional true vector of exogenous shocks V_t by the shocks-vector $\tilde{V}_t = g_y\left(Z_{t|t} - FZ_{t-1|t-1}\right) = g_y L_t(g_t - \bar{g} - HFZ_{t-1|t-1})$ that underlies the filtered estimates $Z_{t|t}$.[10]

3.3 Calibration

For the calibration of the Phillips Curve parameter *relating inflation to marginal cost*, we set $\kappa_{mc} = 0.012$, i.e. towards the low end of empirical estimates [see e.g. Altig et al.(2011), Galí and Gertler (1999), and Lindé (2005)]. If factors were completely mobile, this calibration would imply mean price contract durations of about 10 quarters, but – as emphasized by an extensive literature [e.g., Altig et al. (2011), and Smets and Wouters (2007)] – the reduced form slope could be regarded as consistent with much shorter contract durations under reasonable assumptions about strategic complementarity. The net markup of firms, θ_p, is set to 10 percent (i.e. 0.1).

[10] Notice that even if the true variance of the second state innovation is equal to 0, the second component of $\tilde{V}_t$ will not be if the permanent component follows an AR(2) process.

For other parameters, we adopt a standard quarterly calibration by setting the discount factor $\beta = 0.995$, and steady state net inflation $\pi = .005$ so that $i = .01$. We let $\sigma = 1$ (log utility), the capital share $\alpha = 0.3$, the Frisch elasticity of labor supply $\frac{1}{\chi} = 0.4$, the government spending share $g_y = 0.2$, and the taste shock parameter $\nu_c = 0.01$ (implying $\phi_{mc} = \frac{\chi}{1-\alpha} + \frac{1}{\hat{\sigma}^{open}} + \frac{\alpha}{1-\alpha} = 5.1$, and $\kappa_x = \kappa_{mc}\phi_{mc} = .059$). Steady state government spending is financed by labor income taxes, τ_N, which equals 39 percent in the steady state given our other parameters. As mentioned earlier, variations in g_t around g_y are financed by lump-sum taxes.

In the absence of CU membership, monetary policy completely stabilizes output and inflation (achieved by making γ_π (or γ_x) in Equation 7 arbitrarily large). We will refer to this as *independent monetary policy* (IMP). Finally, the open economy parameters ω and ε_p are set to equal 0.3 and 1.5 respectively.

For government spending, we will consider both front-loaded and gradual consolidations. We start out by studying front-loaded consolidations that comes on line with full force immediately. In this case we assume actual spending to follow an AR(1)-process with a very high persistence (0.999) and which is reduced by 1 percent as share of trend output. The parameters in this case is taken from the estimations for Spain in Section 2 but sets $\rho_1^{perm} = 0$.[11] Additionally, we study the consequences of the fiscal authority proceeding gradually, in which case we use the AR(2)-process for Spain but adjust the size of the initial spending shock so that spending eventually declines by 1 percent as share of trend GDP. For the benchmark value $\rho_1^{perm} = 0.9$, it takes about 5 years before the consolidation comes into full effect.

3.4 Results

We now proceed to discuss the quantitative results in the stylized model. We first discuss the reference case with independent monetary policy (Figure 3), and then turn to the case where the consolidating economy is a small member of a currency union (Figures 4 and 5).

[11] As discussed briefly in Section 2, we decided to use results for Spain to have an intermediate case between full and no credibility. Given the low estimated SNR for Greece, it will behave very closely to the no-credibility-case in the short- and medium-term.

3.4.1 Independent Monetary Policy

Figure 3 provide the results under IMP for three alternative assumptions about credibility, assuming that the actual and permanent spending path follows an AR(1)-near unit root process and that agents observe the actual government spending. The blue solid line shows results under perfect credibility: in this case the government cuts spending aggressively with 1 percent of trend GDP today and everyone believes this cut to be near permanent, as indicated by the solid black line in the bottom panels. The dotted green line shows the no-credibility-case, in which agents within the economy in each period believe that spending will quickly revert back to baseline (0) with the root $\rho^{temp} = 0.8$, as indicated by the thin red lines in the bottom left panel. This simulation follows in't Veld (2013) by assuming that agents never update their expectations regarding the persistence of the cut, although the government keeps actual spending at the same level as under perfect credibility. Finally, the red dash-dotted line shows the imperfect-credibility-case, in which agents solve the signal extraction problem outlined in Section 3.2 to filter out the transient and permanent components of the spending cut in each period. Under learning about the transient and permanent component, a well-known result in the AR(1)-case is that the filtered share of the permanent component in the first period is

$$g_{0|0}^{perm} = \frac{\sigma_{perm}^2}{\sigma_{perm}^2 + \sigma_{temp}^2}, \tag{15}$$

and the transient component will simply be $1 - g_{t|t}^{perm}$.[12] Given our estimates of σ_{perm} and σ_{temp} for the various countries reported in Table 1, it is clear that the filtered permanent component is quite low in the first period. With the estimates for Spain, $g_{0|0}^{perm}$ is a little below 5 percent of the total cut.

Although the spending cut is very persistent, it takes over five years before the permanent component exceeds the transient component as shown in the bottom right panel. Given our calibration of the parameters in learning process, it will take as long as ten years before the permanent component equals three-fourths of the actual spending cut. If using the standard

[12] Throughout the paper, we make the common assumption that the economy starts out in the steady state and that agents in period t have perfect knowledge about $\left\{g_{t-1-s}^{perm}\right\}_{s=0}^{\infty}$ and $\left\{g_{t-1-s}^{temp}\right\}_{s=0}^{\infty}$. This assumption will tend to reduce the filtered permanent component relative to the alternative assumption in which agents do not know the past histories of the permanent and filtered components. On the other hand, our assumption that agents observe the level of g_t instead of its growth rate tends to boost the size of the filtered permanent component in period t.

errors for Greece in Table 1, the permanent component would only constitute about a third of total cut after ten years, so a Greek calibration of the imperfect-credibility-case would have very similar properties as the no-credibility-case in the short- and medium-term. With this in mind, we now discuss the economic consequences of the alternative assumptions on credibility. Within the context of the simple model, the nominal exchange rate and thus the terms of trade, τ_t, depreciates considerably on impact as shown in the next-to-top right panel in the figure. This result can be shown analytically by combining Equations (9) and (8), and recognizing that an unconstrained aggressive monetary policy rule which fully stabilizes inflation will keep actual output at its potential level (as shown by the top left and right panels in the figure). Thus, under IMP, an aggressive policy rule which engineers a sharp depreciation of the nominal exchange rate can keep the paths for τ_t and y_t unaffected by the degree of credibility. Even so, the effects on the potential real rate differ, implying that different paths of the nominal policy rate are called for. In the perfect-credibility-case, r_t^{pot} remains roughly unchanged as it is determined by the expected change in τ_t (see Equation 11). Accordingly, no major cuts in the nominal policy rate are needed; inflation and the output gap can still be kept at target levels.

In the no-credibility-case, however, r_t^{pot} falls substantially because τ_t in each time is expected to start to reverting (i.e. appreciate) back towards its baseline value. This happens because agents in the model do not expect that the spending cut will be long-lasting. Consequently, the central bank needs to cut the policy rate in tandem with the fall in the potential real rate to keep output at potential – and inflation at its targeted – rate. The imperfect-credibility-case is somewhere in between these two polar cases (depending on the signal-to-noise ratio) and thus requires some additional monetary policy accommodation by the central bank. To wrap up, within the context of the simple model outlined above, impaired credibility implies that some additional monetary policy accommodation is needed to ameliorate adverse effects on the output gap and inflation during front-loaded fiscal consolidations. Notice however, that even when the consolidation is perfectly credible, the central bank ensures that output is kept at potential and inflation at target by engineering a sharp depreciation of the nominal exchange rate and the terms-of-trade.

3.4.2 Currency Union Membership

We now redo the same experiment as illustrated in Figure 3, but assume that the consolidating economy is a small member of a currency union. In all other respects, the nature of the experiment remains identical to the IMP-case just discussed.

The CU results are depicted in Figure 4. The direct difference with respect to the IMP results is that neither the nominal exchange rate nor the nominal interest rate changes, as seen in the upper panels. Because the foreign price level p_t^* is unchanged (this follows from our SOE assumption), any changes in the terms-of-trade thus has to happen through movements in domestic inflation when the nominal exchange rate is fixed. Hence, inflation (the next-to-upper-left panel in Figure 4) has to fall in order for the actual τ_t to depreciate and close the gap to the potential terms-of-trade τ_t^{pot} (shown by the dashed black line in the next-to-upper-right panel in Figure 4). Even so, because prices are sticky inflation will not fall enough in the short-term and τ_t will therefore only depreciate gradually, resulting in a significant negative terms-of-trade gap ($\tau_t - \tau_t^{pot} < 0$). This negative terms-of-trade gap triggers a negative output gap according to Equation (12), and output therefore falls below its potential level. This is visible in the next-to-last panel in the left column of the figure.

Currency union membership thus generates a negative output gap and a fall in the inflation, regardless of whether credibility is impaired or not. Nevertheless, the lower the ability of policy makers to establish credibility for the cuts to be long-lasting, the more adverse are the effects on the economy under a CU membership. In the full credibility (FC henceforth) case, actual output falls roughly four times more than potential output initially, but the output gap is closed after roughly four years. In the no credibility (NC, henceforth) case, the sustained decline in output is about three times larger than that of potential output. The imperfect credibility (IC henceforth) case is somewhere in between; sizable losses initially but notably smaller losses compared to the NC case after 3 years. An easy way to understand why the output costs are more substantial and persistent in the NC-case is to look at the real interest rate gap. As we noted in Figure 3, r_t^{pot} falls much more in the no-credibility-case compared to full credibility. Therefore, although the actual real interest rate rises less in the NC-case compared to the FC-case, as seen in the next-to-bottom-right panel in Figure 4, the NC-case is associated with a significantly larger adverse impact on the real interest rate gap ($r_t - r_t^{pot}$) compared to the FC-case. This explains why the output gap falls much less in the FC-case, although the actual real interest rate rises by less in the NC-case. Again, the adverse impact on the real interest rate gap for the IC-case is somewhere in between these limiting cases.

One seemingly inconsistent feature of the behavior of inflation and the output gap (actual less potential output) seen in Figure 4 is that inflation falls more initially under FC although the output gap falls more when credibility is impaired. At first glance, this observation appears inconsistent with the Phillips curve in (6), because a larger and persistent decline in the output gap when credibility is impaired should lead to a lower path for inflation. The key to reconcile these observations is that Figure 4 shows the ex post realized paths for actual and potential output. In "real time", i.e. in periods 0,1,2,...,40, agents believe that when credibility is impaired, spending will retrace back to its pre-consolidation level relatively quickly (see the lower left and right panels). During the first two years this causes the expected deviation between actual and potential output to be smaller when credibility is impaired, and the Phillips curve, which states that inflation today is the discounted sum of future expected output gaps, i.e.

$$\pi_t = \kappa_x \sum_{s=0}^{\infty} \beta^s \mathrm{E}_t x_{t+s},$$

then implies that inflation initially falls less when credibility is impaired. Only after two years, when the output gap is almost closed in the FC-case and a sizable negative output gap persists under imperfect credibility, inflation is more adversely affected in the latter case (both under learning and no-credibility).

Our analysis shows that CU constraints might impose significant headwinds for front-loaded aggressive consolidations to reduce debt at low output costs, especially when credibility is impaired. Some papers in the literature (e.g. Erceg and Lindé, 2013) has therefore suggested that consolidations should be implemented more gradually, as more gradual consolidations does not require the same dose of monetary accommodation as front-loaded consolidations do. We now proceed to show that impaired credibility, in addition to the monetary constraints posed by CU membership, is an additional reason to proceed in a gradual fashion.

As discussed in Section 3.3, we implement a more gradual consolidation profile by letting actual and permanent spending follow an AR(2)-process using the estimated parameters in Table 1, with the exception of ρ_2^{perm} which is reduced from 0.005 to 0.0018 so that the spending decline is equally persistent as in the AR(1)-case. It is imperative to understand that both the front-loaded consolidation approach studied in Figures 3 and 4, and the gradual approach studied in Figure 5, features exactly the same signal-to-noise ratio in the first period as we do not adjust the standard errors of the permanent and transient components in Equation (15) when we switch from the AR(1) to the AR(2)-case. Hence, a higher initial signal-to-noise ratio is not the reason why the filtered permanent component catches up much quicker with the actual spending cut in the gradual case (see the lower right panel in Figure 5). Instead, the reason why the filtered permanent component already swamps the transient component after one year is the profile of the spending cut. Under the assumption that the temporary component follows an AR(1)-process with uncorrelated residuals, agents simply find it more unlikely that several negative temporary shocks cause the gradual decline in actual spending they observe in Figure 5. As such, a gradual path is more credible compared to the front-loaded path studied earlier. This is counter to the conventional wisdom, in which a front-loaded spending cut is meant to build credibility for a persistent spending cut. The conventional view might of course still be right, but our analysis makes clear that it rests on "political capital" arguments and that is not applicable to an environment in which agents solve a signal extraction problem.

Turning to the results shown in Figure 5, we see that the difference between the FC- and IC-cases starts to shrink rapidly already after 8 quarters, reflecting that agents learn rather quickly that the spending cut is very persistent. For the NC-case, there are no differences as the transient component by construction will be the same regardless of whether the consolidation is front-loaded or gradual. In the realistic case however, where there indeed is some learning, Figure 5 shows that private agents faster will learn that the fiscal consolidation is permanent if the consolidation is implemented gradually. Hence, the responses with imperfect credibility is much closer to those obtained under perfect credibility.

Since the different spending profiles in illustrated Figures 4 and 5 makes it hard to compare the relative impact on output, we compute the cumulative spending multipliers as a final exercise. Table 2 shows the present value government spending multiplier suggested by Uhlig (2010), which at horizon K is defined as

$$m_K = \frac{1}{g_y} \frac{\sum_0^K \beta^K \Delta y_{t+K}}{\sum_0^K \beta^K \Delta g_{t+K}}. \tag{16}$$

Thus, the impact multiplier m_0 is simply given by $\frac{1}{g_y}\frac{\Delta y_t}{\Delta g_t}$. Table 2 reports results of the impact for 4, 12, 20, and 40 quarter-cumulated multipliers. The results shows that the cumulative multiplier schedule is flat under IMP, which is able to keep output at its potential level. Given Equation (9), this is to be expected and the multiplier simply equals $\frac{1}{\phi_{mc}\tilde{\sigma}^{open}}$. It is important to notice though, that significantly less monetary accommodation is needed for the gradual consolidation to keep output at its potential level, implying the multiplier to be more elevated in the front-loaded case if monetary policy were able to provide less stimulus (for instance by being constrained by the effective lower bound on interest rates).

Table 2: Cumulative Spending Multipliers.

	Front-loaded Consolidation					Gradual Consolidation				
	CU multiplier									
Cred. Assumption	m_0	m_4	m_{12}	m_{20}	m_{40}	m_0	m_4	m_{12}	m_{20}	m_{40}
No Credibility	0.91	0.81	0.68	0.63	0.59	0.91	0.84	0.72	0.66	0.60
Perfect Credibility	0.84	0.67	0.45	0.37	0.30	0.44	0.40	0.33	0.29	0.25
Imperf. Credibility	0.90	0.80	0.65	0.58	0.48	0.88	0.76	0.50	0.38	0.29
	IMP multiplier – Full Stab.									
All cred. ass.	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21

Note: The CU multiplier is calculated by Equation (16) using the data in Figures 3–5. m_0 is the impact multiplier, and m_K, where $K = 4, 12, 20, 40$ is the cumulative 1-, 3-, 5- and 10-year multiplier. The "Front-Loaded Consolidation" refers to the AR(1)-case, and the "Gradual Consolidation" to the AR(2)- case. The IMP multiplier is the corresponding multiplier when monetary policy provides full stabilization for both consolidation profiles. The schedules are in this case invariant to alternative credibility assumptions, and are simply reported as "All cred. ass".

Turning to the CU results in the first three rows with multipliers in Table 2, we see that the multipliers are highest in the NC-case regardless of whether the consolidation is gradual or front-loaded. In fact, for the NC-case the short-run (m_0) and long-run (m_{40}, subject to rounding) cumulative multipliers are independent of the consolidation profile. This is expected because of the way we add unanticipated shocks to the temporary spending process in order to keep actual spending at the target path in the NC-case. We see, however, that the intermediate horizon multipliers differ somewhat in the NC-case, and this is because the timing of phasing in the unanticipated shocks differ between the front-loaded and gradual consolidation (i.e. the impulse response function of output to spending goes not feature a constant ratio between y_t and g_t).

When credibility if perfect, we see that the multiplier schedule is significantly lower in the gradual case, especially in the shorter-term. A similar finding holds when agents solve the signal-extraction problem (imperfect credibility), with the interesting twist that the short-term multipliers (m_0 and m_4) are relatively high even under under a gradual profile while the long-run multiplier is substantially lower ($m_{40} = 0.29$ instead of 0.48) and quite close to the cumulative multiplier under PC (m_{40} equals 0.25 for this case). However, because relatively small spending cuts are undertaken in the short run under a gradual strategy, the still somewhat elevated multiplier in the short run is less damaging to the level of output compared to a front-loaded strategy. Thus, the results in Table 5 clearly identifies imperfect credibility as an additional reason to pursue consolidations more gradually and confirms the visual results in Figures 4 and 5.[13]

3.4.3 Robustness to Tax Financing

So far, we have assumed that the government use lump-sum taxes to stabilize government debt, but that labor income taxes were used to finance the steady state level of government expenditures. As a consequence, Ricardian equivalence holds in the model, and the path of government debt is inconsequential for the evolution of output following the consolidation. The fact that the labor income tax rate τ_{Nt} remains constant is the key to understand why actual and potential output falls persistently following the fiscal consolidation experiments illustrated in Figures 4 and 5.[14] However, financing through distortionary taxation is argu-

[13] Note that the impact multiplier m_0 may differ in the AR(1)- and AR(2)-cases of the imperfect credibility, although the SNRs for the transient and permanent innovations are the same for both parameterizations. m_0 may differ because the agents, conditional on observing actual spending in period 0, expect that the path for the permanent component will differ. In the AR(1)-case, they essentially believe the permanent component will remain unchanged, and in the AR(2)-case, they expect the permanent spending component to fall even further in future periods (due to the specification of the AR(2)-process). Because the different permanent paths affect the potential and actual real rates differently and that this influences agents' decisions upon impact, these beliefs can cause m_0 to differ under CU membership although the SNR is the same.

[14] Moreover, government and private consumption are modeled as separable in the utility function, so there is no direct rationale for households to increase private consumption following a cut in government

ably more relevant empirically and we therefore now quickly discuss the robustness of our results in this dimension. To do so, we allow for one period government debt and assume that labor income taxes respond to government debt (as share of trend GDP) as deviation from a targeted level of debt, b_{Gt}^{*}, according to the rule

$$\tau_{Nt} - \tau_N = \nu_{\tau 0} \left(\tau_{Nt-1} - \tau_N\right) + \left(1 - \nu_{\tau 0}\right) \nu_{\tau 1} (b_{Gt} - b_{Gt}^{*}).$$

To convincingly argue that allowing for distortionary taxes strengthens our argument that credibility matters, we consider the effects of an aggressive rule by setting the smoothing parameter ν_{τ_0} to 0.7 and $\nu_{\tau_1} = \frac{1+\theta_p}{1-\alpha} = 1.57$. Our chosen response coefficient for ν_{τ_1} implies that the labor income tax rate responds to a one percent wedge between the actual and targeted debt levels by the equivalent of one percent of GDP in the long run. With this tax-rule, we repeat the front-loaded consolidation experiment shown in Figure 4, keeping all other aspects of the experiment unchanged. The results are illustrated in Figure 6, where the panels in the left column gives the results for when the debt target b_{Gt}^{*} is unchanged, whereas the right column shows results when the debt target is reduced in line with how much actual debt b_{Gt} is expected to fall after 10 years under perfect credibility. We see from the left column in Figure 6 that potential output expands in the perfect credibility case after three years already, under labor income tax financing. This reflects that τ_N is cut fairly aggressively to stabilize government debt around the unchanged target (see the third panel in the left column), and this has benign labor-supply effects. The positive supply-side effects of a reduction in τ_N becomes most beneficial when the spending cuts are expected to be long-lasting, which explains why potential output expands more under perfect credibility and less when credibility is impaired. This contrasts to the results under lump-sum financing (Figure 4) where the impact on potential output were shown to be invariant to the degree of credibility.

Actual output, shown in the second panel in the first column of Figure 6, also expands after two years under perfect credibility as the cut in spending raises the fiscal surplus and allows the government to cut the actual labor income tax rate, as shown in the bottom left panel of the figure. When credibility is impaired, the output gains emerges more

consumption.

slowly because potential output also rises more slowly (as explained above) and the output gap is more adversely impacted. Under our calibration however, actual output eventually rises under learning, whereas it remains negative if no credibility gains materialize (the no-credibility-case).

The right column of Figure 6 illustrates that there is no need for the government to cut τ_N aggressively in the more realistic case when the decline in spending goes together with cut in the targeted debt level b^*_{Gt}. With our debt target path – the black dashed line in the third panel – the government even needs to raise τ_N somewhat initially as actual debt b_{Gt} does not shrink as fast as b^*_{Gt} in the near term due to the initial fall in economic activity (and associated reduction in tax revenues).[15] As can be seen from the first and second panel, potential output falls persistently and just barely returns to nil when credibility is not impaired; when credibility is impaired potential output falls throughout the horizon. As a consequence, there is a significant and persistent fall in actual output, especially under learning, and the results do not differ much from those under lump-sum taxation shown in Figure 4.

Our conclusion is that if the government has the fiscal space to pair spending reductions with cuts in distortionary taxes, then output will eventually expand if the government eventually gains credibility for that the spending cuts will become long-lasting. Nevertheless, as evidenced in Figure 6, there is a considerable cost to fiscal consolidation under distortionary taxes adjustment when credibility is impaired. Moreover, in the current situation when the spending cuts are not paired with tax cuts – if anything, rather the opposite – our results do not appear to be particularly sensitive to lump-sum or distortionary taxation.

4 Robustness in a Large-Scale Open Economy Model

In this section, we examine the robustness of our results from Section 3 in a fully-fledged open economy model. Before we turn to the results in Sections 4.3 and 4.4, we provide a

[15] We assume b^*_{Gt} to follow the AR(2)-process in Equation (18), and set the size of the debt target shock so that the gap between b_{Gt} and b^*_{Gt} is small after 10 years under perfect credibility and little tax adjustment. Hence, we implicitly assume that the spending cut is appropriately sized to reduce b_{Gt} as targeted. In addition, we assume that the reduction in b^*_{Gt} is anticipated by all agents; in the cases with impaired credibility this implies that labor income taxes will be projected to increase more relative to when credibility is perfect.

model overview with a focus on the modeling of fiscal policy, and discuss the calibration of some key parameters. A complete description of the model is available in Appendix A.

4.1 The Model

The model is adopted from Erceg and Lindé (2010, 2013) aside from some features of the fiscal policy specification (as discussed in further detail below), and consists of two countries (or country blocks) that differ in size, but are otherwise isomorphic. The first country is the home economy, or "Periphery", while the second country is referred to as the "Core." The countries share a common currency and monetary policy is conducted by a single central bank, which adjusts policy rates in response to the aggregate inflation rate and output gap in the currency union. By contrast, fiscal policy may differ across the two blocks. Given the isomorphic structure, our exposition below largely focuses on the structure of the Periphery.

Abstracting from trade linkages, the specification of each country block builds heavily on the estimated models of Christiano, Eichenbaum, and Evans (2005) (CEE henceforth), and Smets and Wouters (2003, 2007) (SW henceforth). The model thus features sticky nominal wages and prices (allowing for some intrinsic persistence in both price- and wage-setting), external habit persistence in consumption, and embeds for a Q-theory investment-specification modified so that changing the level of investment (rather than the capital stock) is costly. However, our model departs from CEE and SW in two substantive ways. First, we assume that a fraction of the households are "Keynesian", and simply consume their current net income. This evidently contrasts with the analysis in our stylized model which assumed that all households made consumption decisions based on their permanent income. Galí, López-Salido, and Vallés (2007) shows that the inclusion of non-Ricardian households helps account for structural VAR evidence indicating that private consumption rises in response to higher government spending. Second, we incorporate a financial accelerator following the basic approach of Bernanke, Gertler, and Gilchrist (1999).

On the open economy dimension, the model assumes producer currency pricing as in the benchmark model, but allow for incomplete international financial markets (the stylized model in Section 3 presumed complete financial markets both domestically and internationally).

To analyze the behavior of the model, we log-linearize the model's equations around the non-stochastic steady state. Nominal variables are rendered stationary by suitable transformations. To solve the unconstrained version of the model, we compute the reduced-form solution for a given set of parameters using the numerical algorithm of Anderson and Moore (1985), which provides an efficient implementation of the solution method proposed by Blanchard and Kahn (1980). Since the Periphery is assumed to be small relative to the Core country block, there is no need to take the zero lower bound (ZLB) into account as the actions of the Periphery will only have an negligible impact on the currency union as a whole.

The approach of analyzing the impact of imperfect credibility for fiscal consolidation is the same as in the stylized model, but because we also are interested in assessing the implications for the evolution of government debt, some further details on the modeling of debt stabilization are in order.

As outlined in more detail in the full model exposition in Appendix A, we presume that governments in Periphery and the Core has the capability to issue debt. In our benchmark specification, we further assume that policymakers in the absence of discretionary spending adjust labor income taxes gradually to keep both the debt-to-GDP ratio, the b_{Gt}, and the gross deficit Δb_{Gt+1}, close to their targets (the latter two denoted b^*_{Gt} and Δb^*_{Gt+1}, respectively). Thus, the labor tax rate evolves according to:

$$\tau_{Nt} - \tau_N = \nu_{\tau_0} \left(\tau_{Nt-1} - \tau_N \right) + \left(1 - \nu_{\tau_0} \right) \left[\nu_{\tau_1} (b_{Gt} - b^*_{Gt}) + \nu_{\tau_2} (\Delta b_{Gt+1} - \Delta b^*_{Gt+1}) \right]. \quad (17)$$

Hence when the government cuts the discretionary component of spending g_t, in order to reduce government debt, we assume that the labor income tax τ_{Nt} gradually will deviate from its steady state value τ_N if a gap emerges between actual and desired debt and deficit levels.[16]

Our main simulations assume that the government in the Periphery reduces its debt target b^*_{Gt}. It is realistic to assume that policymakers would reduce this target gradually to

[16] Lower case letters are used to express a variable as a percent or percentage point deviation from its steady state level. Note that real government debt $b_{G,t}$ is defined as a share of steady state GDP and expressed as percentage point deviations from their steady state or "trend" values. That is, $b_{G,t} = \left(\frac{B_{G,t}}{P_t Y} \right) - b_G$, where $B_{G,t}$ is nominal government debt, P_t is the price level, and Y is the real steady state output. Notice also that $b_{G,t+1}$ is debt outstanding at the end of period t (i.e. debt at the beginning of period $t+1$), so that $\Delta b_{G,t+1}$ is the gross deficit in period t. Analogous notation applies to b^*_{Gt+1}.

help avoid potentially large adverse consequences on output. To capture this gradualism, we assume that the (end of period t) debt target b^*_{Gt+1} follows an AR(2) process (written below on "error-correction" form):

$$b^*_{Gt+1} - b^*_{Gt} = \rho_{d_1}(b^*_{Gt} - b^*_{Gt-1}) - \rho_{d_2} b^*_{Gt} + \varepsilon_{d^*,t}, \tag{18}$$

where the coefficient ρ_{d_1} is set to 0.99 and ρ_{d_2} is set close to zero (i.e. 10^{-8}) so that the reduction in debt is gradual ($\rho_{d_1} > 0$) and essentially permanent ($\rho_{d_2} \approx 0$). The target path for the Periphery government debt is plotted in Figure 7 (the black dashed line) and as to closely mimic the actual debt path under full credibility (the blue solid line). Thus, in the full credibility case, there is little movement of the labor income tax rate as the gap between actual and desired debt and deficit levels is negligible.

The Core is assumed to simply follow an endogenous tax rule as in Equation (17), but does not change its debt target.

4.2 Calibration

Here we discuss the calibration of the key parameters pertaining to fiscal policy and trade. The remaining parameters – which are with a few exceptions adopted from Erceg and Lindé (2013) – are reported and discussed in Appendix A.

The model is calibrated at a quarterly frequency. Structural parameters are set at identical values for each of the two country blocks, except for the parameter determining population size ζ (as discussed below), the fiscal rule parameters, and the parameters determining trade shares.

The parameters pertaining to fiscal policy are intended to roughly capture the revenue and spending sides of euro area government budgets. The share of government spending on goods and services is set equal to 23 percent of steady state output. The government debt to GDP ratio, b_G, is set to 0.75, roughly equal to the average level of debt in euro area countries at end-2008. The ratio of transfers to GDP is set to 10 percent. The steady state sales tax rate τ_C (i.e. the value added tax) is set to 0.20, while the capital tax τ_K is set to 0.30. Given the annualized steady state real interest rate (2 percent), the government's intertemporal budget constraint implies that the effective labor income tax rate τ_N equals

34 percent (0.34) in steady state. The coefficients of the tax adjustment rule in (17) are set so that labor income taxes respond very gradually, which is achieved by setting $\nu_{\tau_0} = 0.9$, $\nu_{\tau_1} = 0.2$ and $\nu_{\tau_2} = 0.5$. This implies that τ_{Nt} in the long-run is decreased (increased) by 0.2 percentage points in response to target deviations from debt ($b_{Gt} - b^*_{Gt}$), and deficit ($\Delta b_{Gt+1} - \Delta b^*_{Gt+1}$) with 0.5 percentage points. However, because ν_{τ_0} is high, the short-run response is substantially smaller. For the Core, we assume the same unaggressive tax rule.

The size of the Periphery is calibrated to be a very small share of euro area GDP, so that $\zeta = 0.02$. This corresponds to the size of Greece, Ireland or Portugal in euro area GDP. Identifying the mentioned countries as the Periphery to calibrate trade shares, the average share of imports of the Periphery was about 14 percent of euro area GDP in 2008 (based on Eurostat). This pins down the trade share parameters ω_C and ω_I for the Periphery under the additional assumption that the import intensity of consumption is equal to three fourths of investment. Given that trade is balanced in steady state, this calibration implies a very small export and import share for the Core countries as share of GDP. Finally, in contrast to the stylized model, risk-sharing is incomplete between the two members of the currency union, but the quantitatively implications of the incompleteness is kept modest by setting the financial intermediation parameter ϕ_b to a very small value (0.00001, which is sufficient to ensure the model to have a unique steady state).

4.3 Benchmark Results

The results in the benchmark calibration of the workhorse model are illustrated in Figure 7 for the CU-case. The left column shows results for the front-loaded cuts which follows the AR(1)-process in Figure 4, while the right column shows results for the gradual spending cut which follows the AR(2)-process shown in Figure 5.[17] The results in the left column are thus comparable to the results in Figure 4, whereas the results in the right column are comparable to those reported in Figure 5.

[17] The difference with respect to the simulations plotted in Figures 4 and 5, is that the large-scale model features a reduction in the debt target b^*_{Gt} which follows the same path as shown in the right column of Figure 6. In the AR(2)-case, the maximum cut in government spending is somewhat higher than the 1 percent cut in the front-loaded one, so that the gap between b_{Gt} and b^*_{Gt} is closed after 10 years under full credibility. Essentially, this means that the 10-year net present value of the spending cut is the same in both the AR(1)- and AR(2)-cases.

Turning to the results depicted in Figure 7, we see that the main features are very similar to those reported for the stylized model. In the front-loaded consolidation case, the potential real rate falls the most in the no-credibility-case and the least under the perfect-credibility one, but because the Periphery is a small member of the currency union, nominal interest rates in the Periphery and the Core are essentially unaffected. Although inflation falls more initially when credibility is perfect, and actual real rates therefore rise more than when credibility is impaired, the real interest rate gap (i.e. the difference between actual and potential rate) is larger. As a result, output falls substantially more when credibility is impaired and the progress to reduce debt is significantly slower, implying that a large wedge between actual- and target-level of government debt opens up. This is particularly the case under no-credibility, when debt is essentially unaffected for almost three years in our calibration. In this case the unresponsiveness of government debt to the GDP-ratio reflects lower tax revenues and higher service costs of debt, additionally to the fact that GDP itself falls.

When spending is cut gradually, we see from the right column in Figure 7 that the cost of imperfect credibility is very low if the government gradually gain credibility for the cuts to be long-lasting. Only if the government never gains any credibility for its spending cuts, will the output costs be comparable to those under a front-loaded consolidation. Computing the cumulative multiplier according to the formula in Equation (16), we find that $m_{40} = 1$ when the consolidation is front-loaded, and 0.75 in the gradual case under learning. Since m_{40} is roughly identical under full credibility (0.73 and 0.70 in the AR(1)- and AR(2)-cases respectively), we can conclude that the bulk of differences under learning indeed stems from learning, and not the spending cut profile.[18]

One key question is to what extent the degree of price- and wage-stickiness affects our result that front-loaded cuts are associated with large output costs under learning. In Appendix B we study the robustness of the results when allowing for faster wage and price-adjustment. We find that if both wages and prices adjust much quicker than in our benchmark calibration, the costs of imperfect credibility diminishes materially.[19] This could potentially be seen as

[18] As in the stylized model, m_{40} is roughly identical (1.05) in the no-learning case.

[19] However, we also show in the appendix that even if prices adjust much more quickly than in our benchmark calibration, our results hold up as long as wage adjustment is sufficiently slow.

a serious weakness of our paper, but given the very modest turn downs in domestic inflation rates amid large declines in economic activity (see Figure 1), our benchmark calibration with slow price adjustment seems strongly supported by the data. Even if the relatively fast adjustment of unit labor cost may call for a higher degree of wage flexibility than employed in our benchmark simulations, we also show (in the appendix) that allowing for faster wage adjustment is inconsequential for our basic result as long as prices are sufficiently sticky.

The finding that either slow price or wage adjustment (or a combination of them) is needed to generate sizable costs of impaired credibility, is perhaps easiest seen from the Phillips curve in (6). We know that under slow price adjustment (i.e. a low κ_x), inflation reacts very slowly to a given change in the path of marginal costs so that the price markup gap is closed very gradually. In the simple sticky price model analyzed in Section 3, the sub-optimal inflation response elevates the government spending multiplier for transient spending cuts in a currency union [Corsetti, Kuester, and Müller (2011), and Erceg and Lindé (2012) provides further details on this topic]. The workhorse model analyzed in this section, which also features sticky wages, generates large multipliers for transient spending shocks because slow wage adjustment causes marginal costs itself to move too little in the first place. As a result, the inflation response is too muted even if prices are not that sticky.

4.4 Results with Endogenous Spreads

In the benchmark calibration of the model, we assumed that interest rates faced by the government and banks in the Periphery and Core, were equal to the currency-area interest rate set by the CU-central-bank (notwithstanding a tiny difference to imply stationary dynamics of Periphery net foreign assets). To examine conditions under which fiscal consolidation may be expansionary, we follow Erceg and Lindé (2010) and Corsetti et al. (2012) and assume that the interest rate faced by the government and banks in the Periphery equals the interest rate set by the CU-central-bank added with a risk-spread which depends positively on the government deficit- and debt-level. If we let i_t^{Per} denote the interest rate in Periphery, we thus have

$$i_t^{Per} - i_t = \psi_b(b_{Gt+1} - b_G) + \psi_d(b_{Gt+1} - b_{Gt}), \tag{19}$$

where we recall that b_{Gt+1} is the end-of-period t government debt level and i_t the interest rate set by the CU-central-bank. The specification in (19) is motivated by the spread equation estimated by Laubach (2010) for the euro area, and captures the idea that countries with high government deficits and debt levels face higher spreads due to a higher risk of default. There is a substantial empirical literature that has examined the question of whether higher deficits and debt lead to increasing interest rates, but it at best has provided mixed evidence in favor of positive values of ψ_b and ψ_d [see e.g. Evans (1985, 1987)]. However, this literature have typically used data from both crisis- and non-crisis periods, and as argued by Laubach (2010), this approach is likely to bias the estimates downwards since the parameters tend to be positive in crisis periods only (close to zero in non-crisis periods). As we are examining the effects of fiscal consolidations under fiscal stress (i.e. high actual and projected debt and deficit) periods, we believe it is worthwhile to entertain the assumption that ψ_b and ψ_d are both positive.

As a tentative calibration, we set $\psi_b = 0.02$ and $\psi_d = 0.04$, implying that a one percent decline in government debt decreases the spread by 2 basis points, and that a one percent decline in the budget deficit decreases the spread with 4 basis points. While these elasticities are somewhat on the upper side relative to the evidence reported by Laubach (2010), they are nevertheless useful to help gauge the potential implications of this channel. All other aspects of the experiment remains the same as described in Section 4.3.

The results for endogenous spreads are illustrated in Figure 8. Observable is that the output costs of aggressive spending-based consolidation can be reduced substantially if long-term interest rate spreads fall (upper left panel), especially when the degree of credibility to follow through and make the spending cuts permanent, is high. In our specific calibration, long-term spreads in the Periphery fall enough in order for the consolidation to have expansionary effects on the economy after roughly two years, even under imperfect credibility (dash-dotted red line). Consequently, these results presents a favorable case for the view that aggressive consolidation can be an efficient tool to reduce public debt at low output cost. However, it is important to point out that this finding crucially hinges on how the consolidation program is implemented, and the results may be much less benign under an alternative – arguably equally empirically realistic – modeling of the consolidation program.

Specifically, we assume the government to drop the gradual labor income tax rule in (17) and instead use government spending entirely to achieve its fiscal targets. Thus, total government spending g_t^{tot} is now comprised of an endogenous component g_t^{endo}, as well as the discretionary component g_t, which as previously. Following Erceg and Lindé (2013), g_t^{endo} is assumed to adjust endogenously according to

$$g_t^{endo} = \nu_{g_0} g_{t-1}^{endo} + (1-\nu_{g_0}) \left[\nu_{g_1} \left(b_{Gt} - b_{Gt}^* \right) + \nu_{g_2} \left(\Delta b_{Gt+1} - \Delta b_{Gt+1}^* \right) \right]. \tag{20}$$

In this alternative specification, the Periphery labor income tax rate is assumed to be constant (at its steady state value of τ_N). The Core is still assumed to use the labor income tax rule to stabilize debt though. We rather assume aggressive coefficients in the spending rule (20) by setting $\nu_{g_0} = 0.8$, $\nu_{g_1} = -1$, and $\nu_{g_2} = -0.5$. Given our steady-state share of government spending (0.23), these coefficients implies that g_t^{endo}, is decreased by 0.25 and 0.125 percent of trend GDP in the long run, as response to target deviations from debt $(b_{Gt} - b_{Gt}^*)$ and deficit $(\Delta b_{Gt+1} - \Delta b_{Gt+1}^*)$ respectively. In the short-run, our choice of ν_{g_0} implies that the response is reduced by 4/5.

In Figure 8 we compare results of the gradual labor income tax rule with the above-mentioned more aggressive spending-based rule to stabilize debt and deficits around their targets when interest rate spreads are endogenous. We focus on the case with imperfect credibility, implying that the results given by the solid blue lines just restate the results shown by the dash-dotted red lines in Figure 7. The results suggests that the more aggressive spending-based rule is much less benign.

In a nut-shell, the government ends up chasing its own tail and cuts spending too much in the near-term and in turn, this causes output to fall largely and debt to rise in the short- and medium-term. Reflecting the rise in government debt and deficits, interest rate spreads therefore go up in the short- and medium-term before starting to fall. The results shown in Figure 8 highlights that the short-run costs can be substantial if policymakers implement too aggressive and front-loaded spending-based consolidations when aggregate demand is weak and credibility is impaired. They also suggest that it may take quite some time before the consolidation efforts carry fruit and have the desired effects under unfavorable conditions.

5 Conclusions

Our paper focuses on the economic implications imperfect credibility may have for expenditure-based fiscal consolidation. We find that credibility is likely to be less of an issue if monetary policy can provide suitable degree of accommodation, whereas imperfect credibility may be a source of substantially larger output losses when monetary policy is constrained by CU membership (or the zero lower bound). In this latter situation, progress in reducing government debt as share of GDP may also be significantly slower.

We also establish that a gradual approach to consolidation within a learning framework is likely to build credibility over the long-lasting nature of the cuts much faster than a front-loaded approach with sharp cuts upfront. This finding is contrary to conventional wisdom whereby large front-loaded spending cuts work like a "regime-shifter" and immediately build credibility that the cuts will become persistent. While the conventional wisdom might be right, our analysis makes clear that it rests on "political capital" arguments and is not supported within an environment where agents use historic spending behaviour to solve a signal extraction problem in order to filter out transient and persistent movements in government spending.[20]

Although we only focus on one type of spending cut to highlight the importance of monetary constraints for fiscal consolidation, actual consolidation programmes deploy a wide array of fiscal spending adjustments. The transmission of these alternative fiscal measures to the real economy may differ substantially from the one considered, with potentially significant consequences. For instance, infrastructure spending presumably boosts the productivity of private capital, while spending on education enhances the longer-term productivity of the workforce. Cuts in these areas would presumably then have more adverse effects on the economy's longer-term potential output than in our framework, which does not take account

[20] Recent empirical results by Perez et al. (2015) suggest that the regime-shift argument is relevant by showing that government (consumption) targets convey useful information about ex-post policy developments when policy changes significantly (even if past credibility is low). On the other hand, long-term interest rate spreads on government bonds in consolidating peripheral euro area members (which should be tightly linked to fiscal credibility), did not fall noticeably on the announcement of austerity plans during the European debt crisis. Rather, as argued by De Grauwe and Ji (2014), they seem to retrace towards pre-crisis levels due to positive market sentiment after the ECB initiated its Outright Monetary Transactions (OMTs), and after the establishment of the European Financial Stability Facility (EFSF) and European Financial Stabilization Mechanism (EFSM).

of these effects, and possibly weaken aggregate demand more even over shorter horizons. On the other hand, reducing certain types of transfers might have less adverse effects than the cuts we consider, particularly in the long run. For example, a gradual tightening of eligibility requirements for unemployment benefits might well reduce the natural rate of unemployment in the long-run, and hence raise potential output.[21] In future research, it would be desirable to extend our modeling framework to better capture the implications of a wider range of potential spending cuts.

Some other extensions of the basic modeling framework would also be useful. First, it would be of interest to extend our approach to imperfect credibility with the approach of Debortoli and Nunes (2012). Finally, our model assumes that the government issues only one-period nominal debt. Allowing for multi-period nominal liabilities could have potentially important consequences for the evolution of government debt.

[21] The near-term effects of transfers are likely to depend on how the transfers are distributed across households. In this vein, recent research using large-scale policy models (Coenen et al., 2012) suggests that cuts in transfers that are concentrated on households facing liquidity constraints – the HM households in our set-up – are likely to be associated with a larger multiplier compared to cuts to general transfers to all households.

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Figure 1: Debt, output, inflation and ULC in Peripheral Economies and the Euro Area

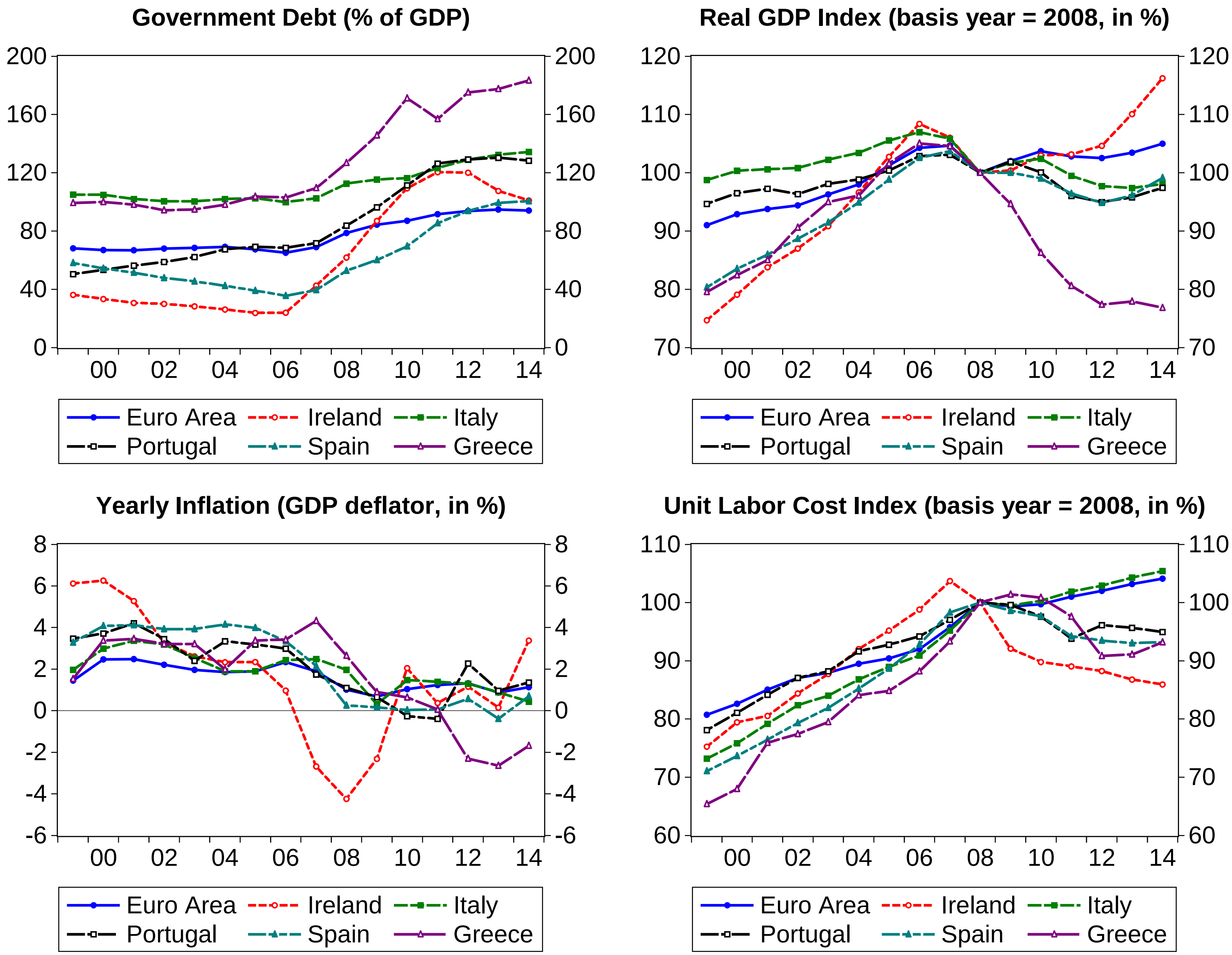


Figure 2: Decomposing Government Consumption (in % of trend GDP)

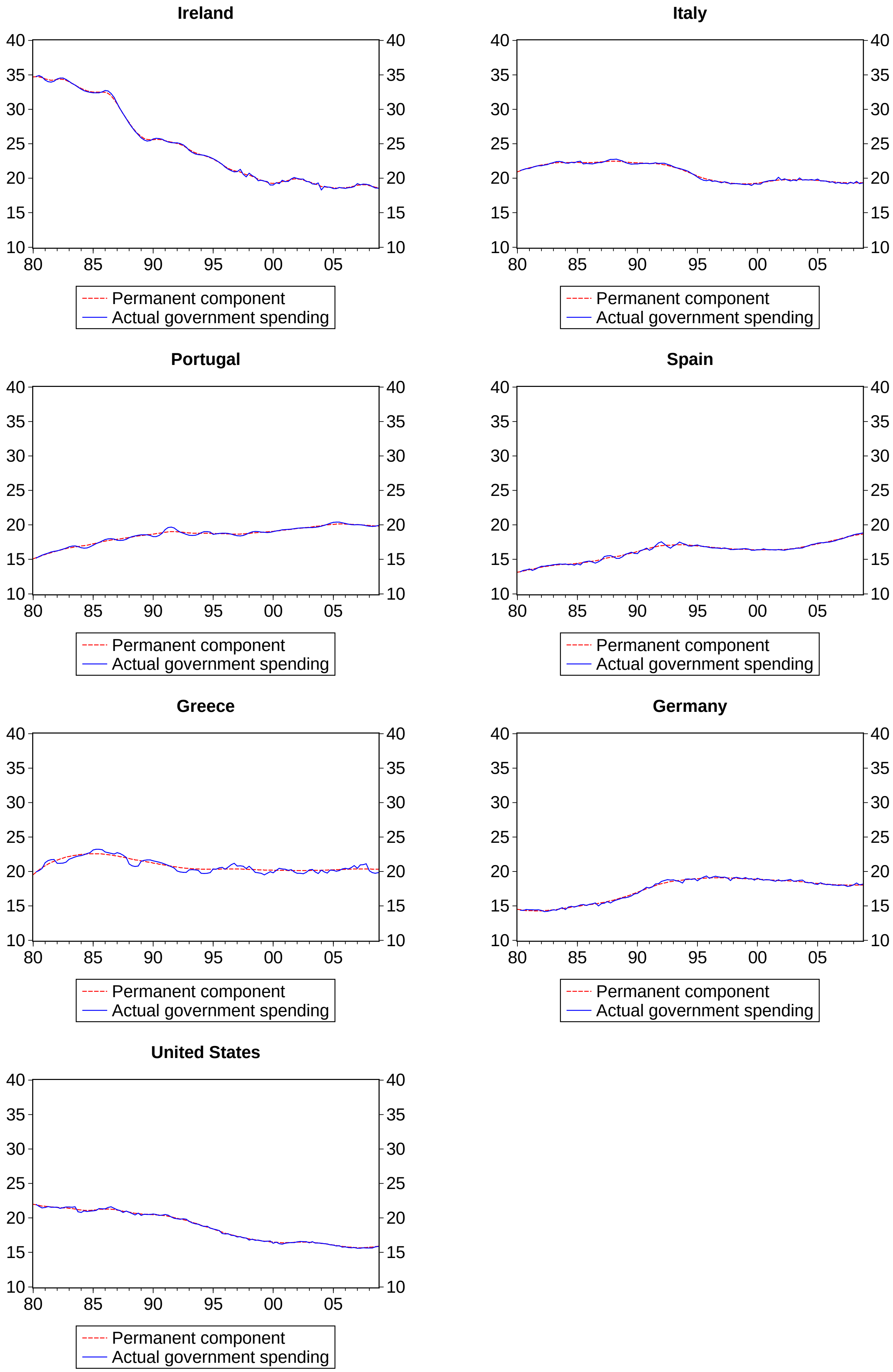


Figure 3: Fiscal Consolidation Under Alternative Assumptions About Credibility: Independent Monetary Policy.

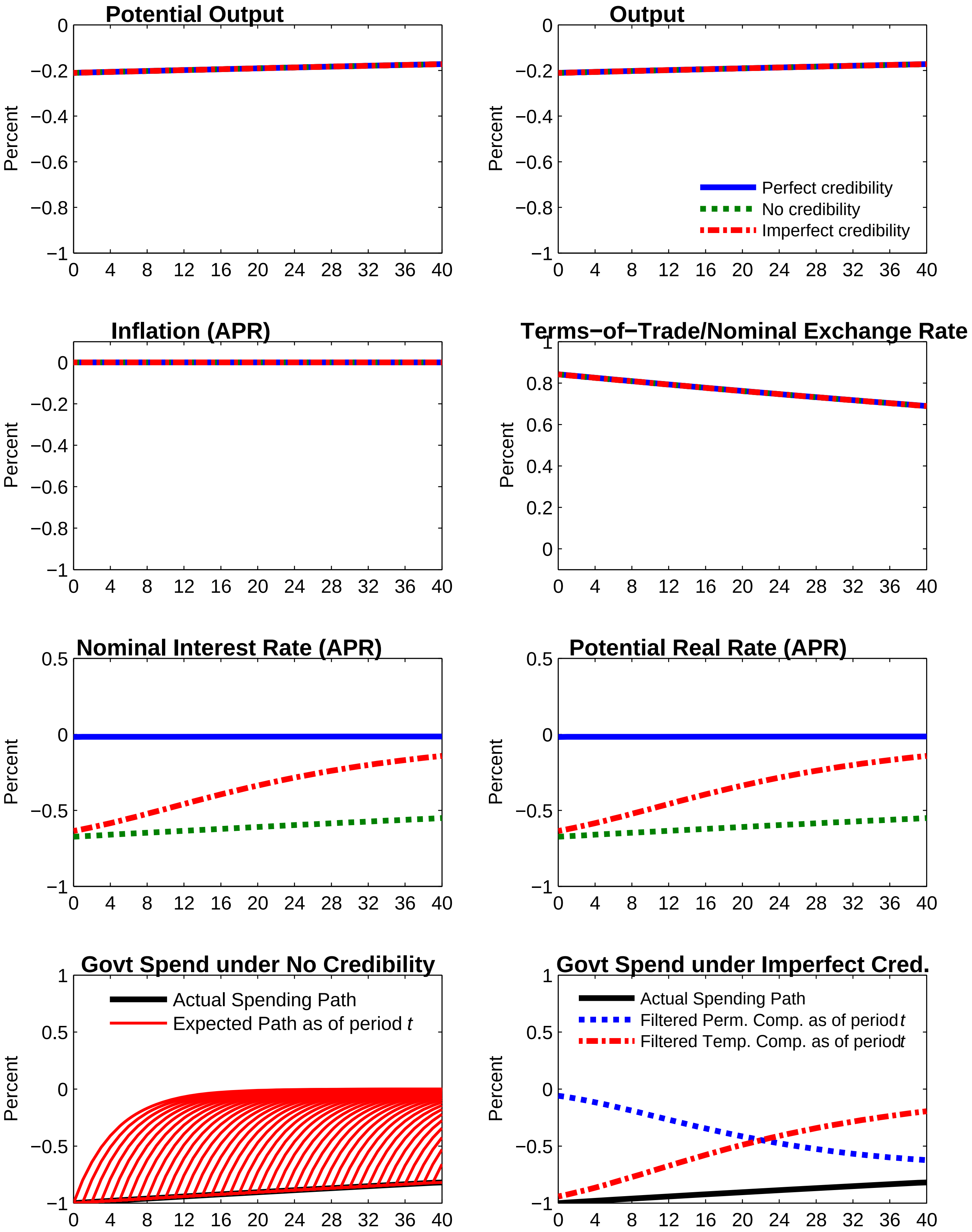


Figure 4: Fiscal Consolidation Under Alternative Assumptions About Credibility: Currency Union Membership.

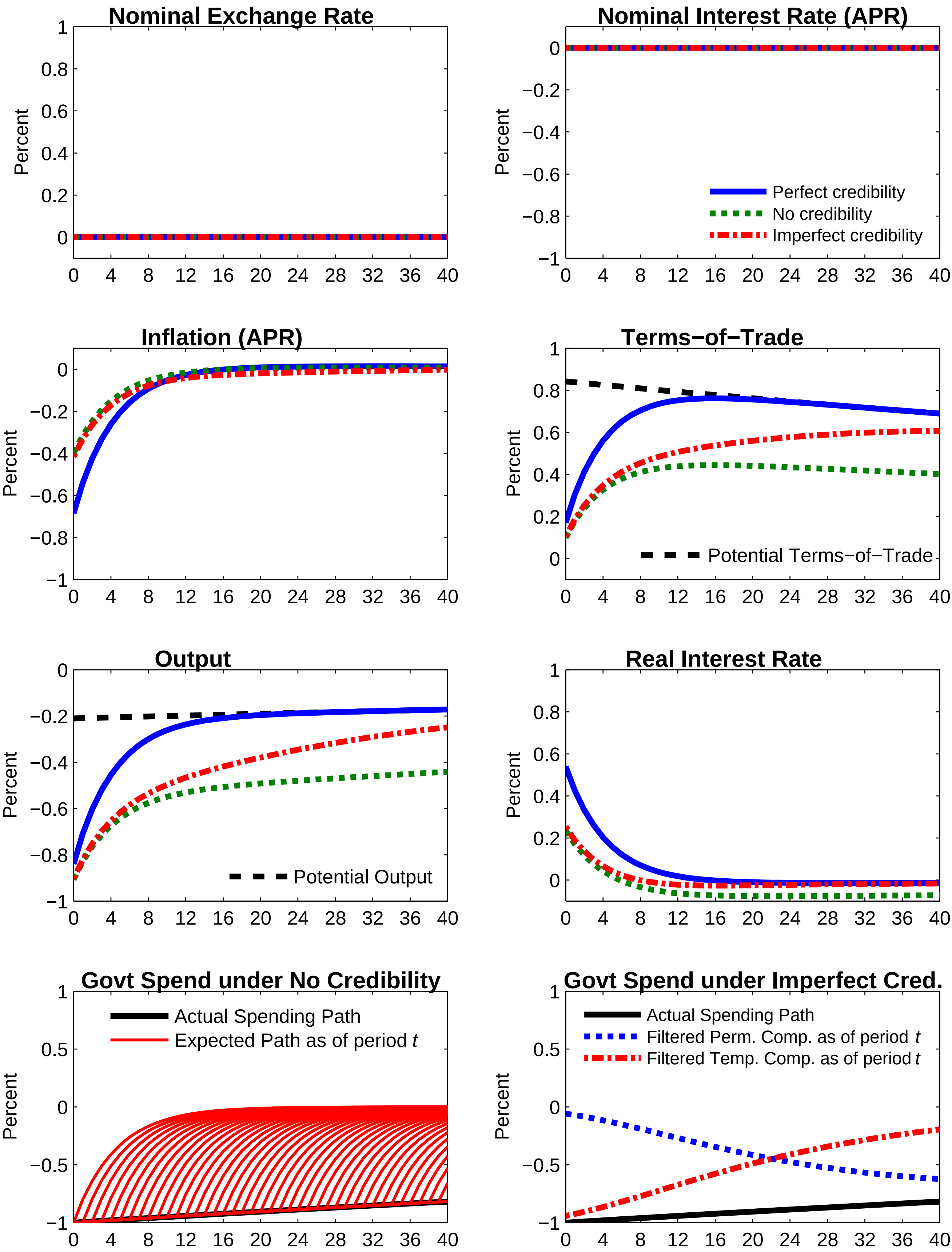


Figure 5: Gradual Fiscal Consolidation Plan Under CU Membership.

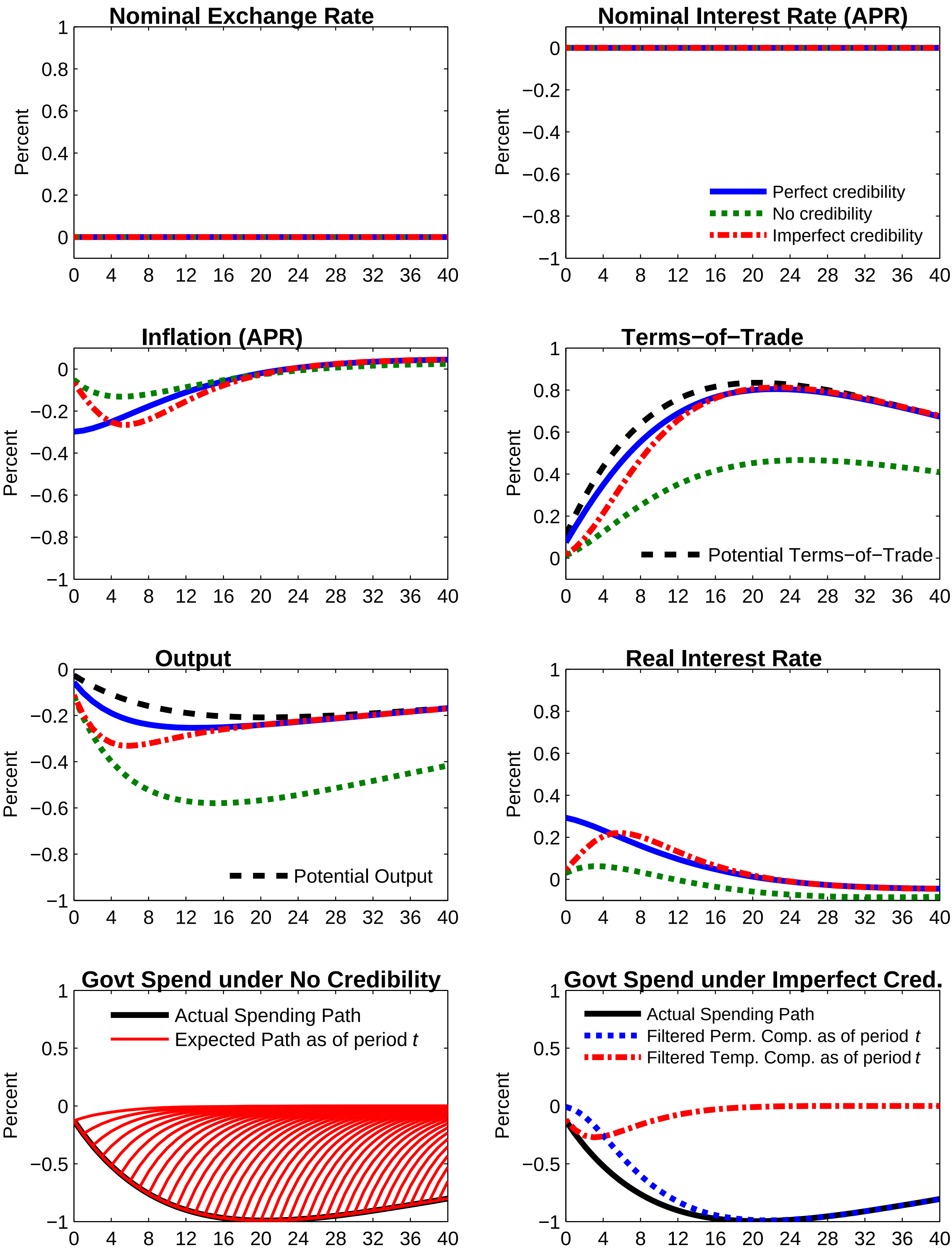


Figure 6: Fiscal Consolidation With Distortionary Taxes in Small CU Member.

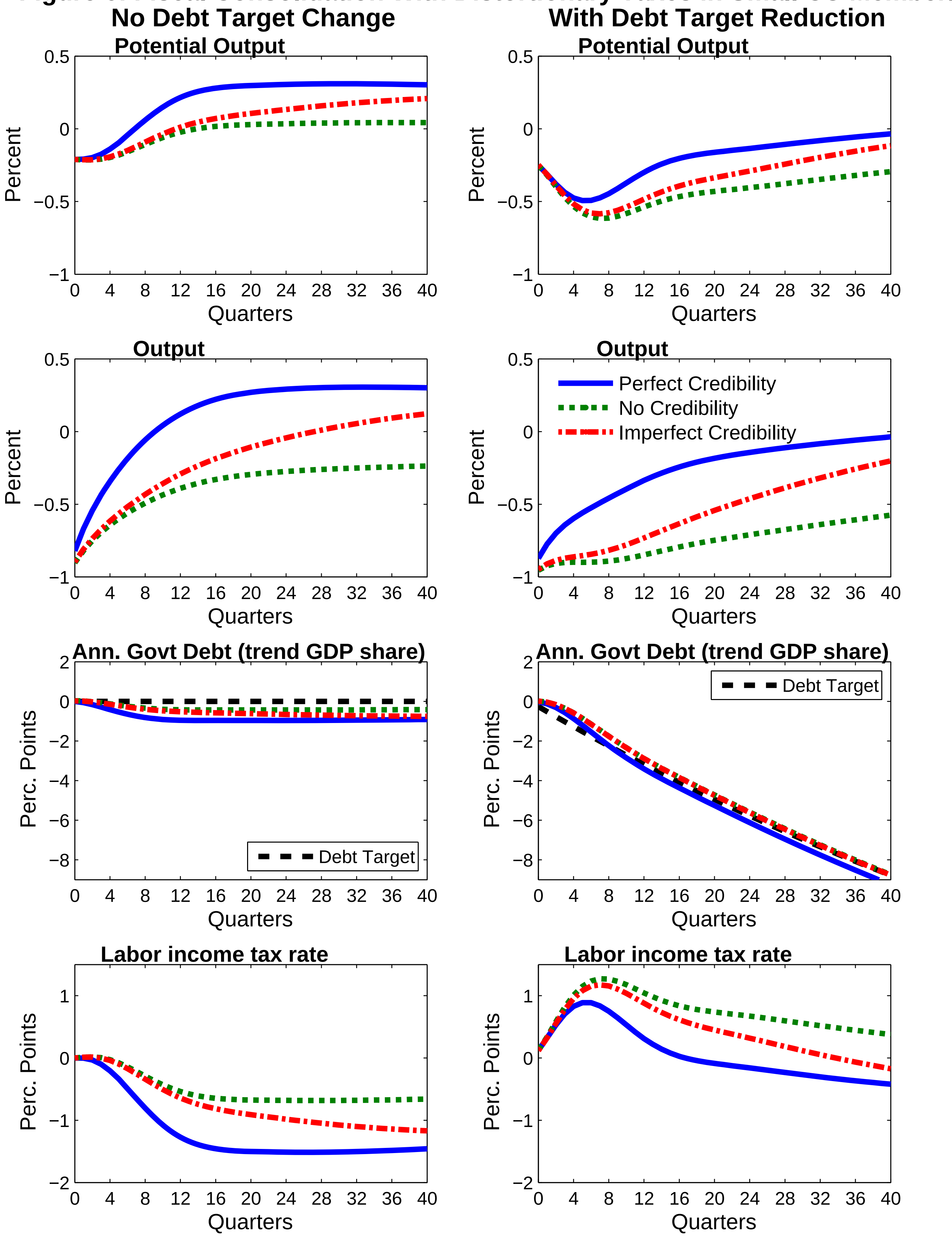


Figure 7: Fiscal Consolidation for Small CU Member in Large Scale Model.

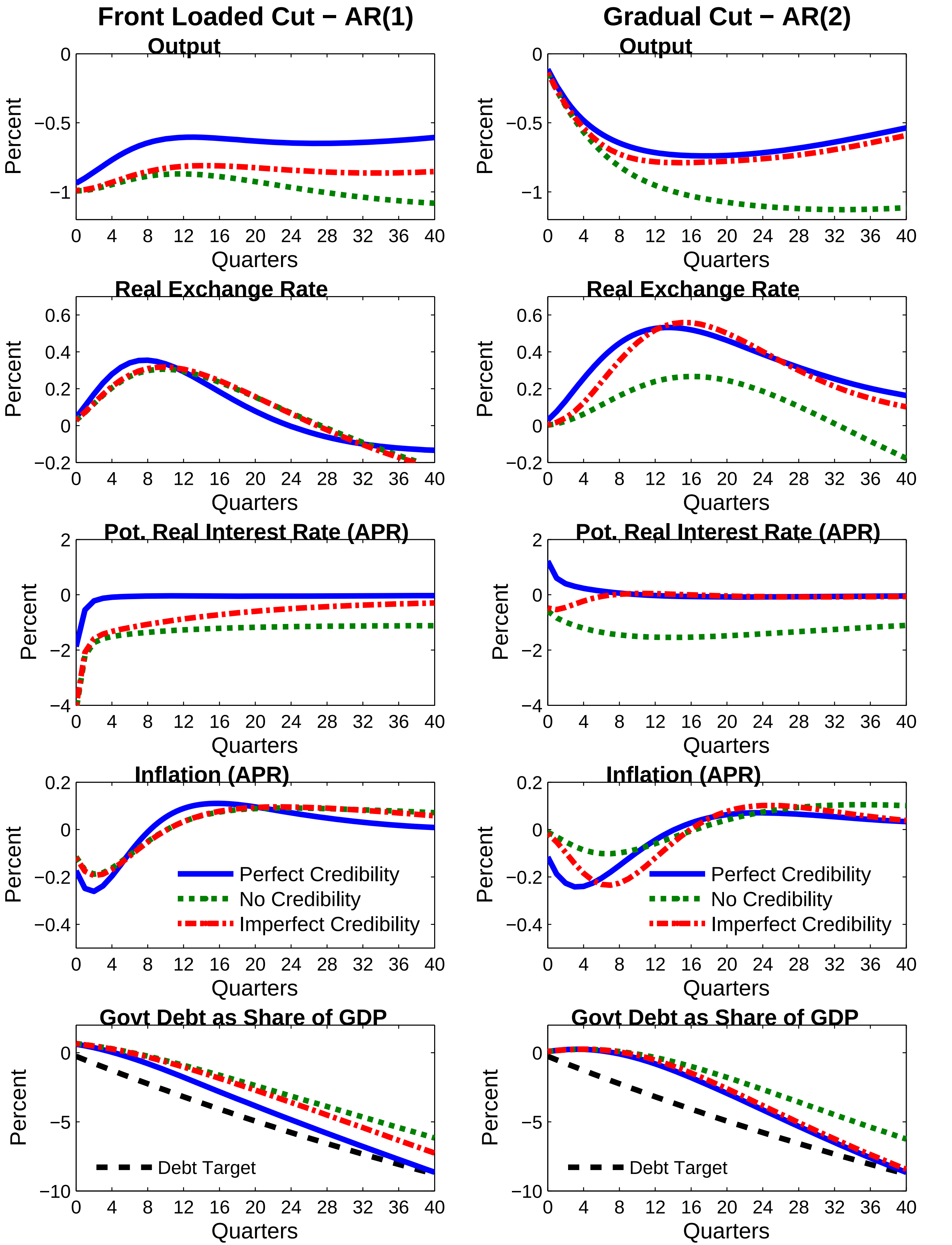


Figure 8: Fiscal Consolidation In Large Scale Model in Small CU Member When Allowing For Endogenous Interest Rate Spreads: Gradual Tax Debt−Deficit Rule.

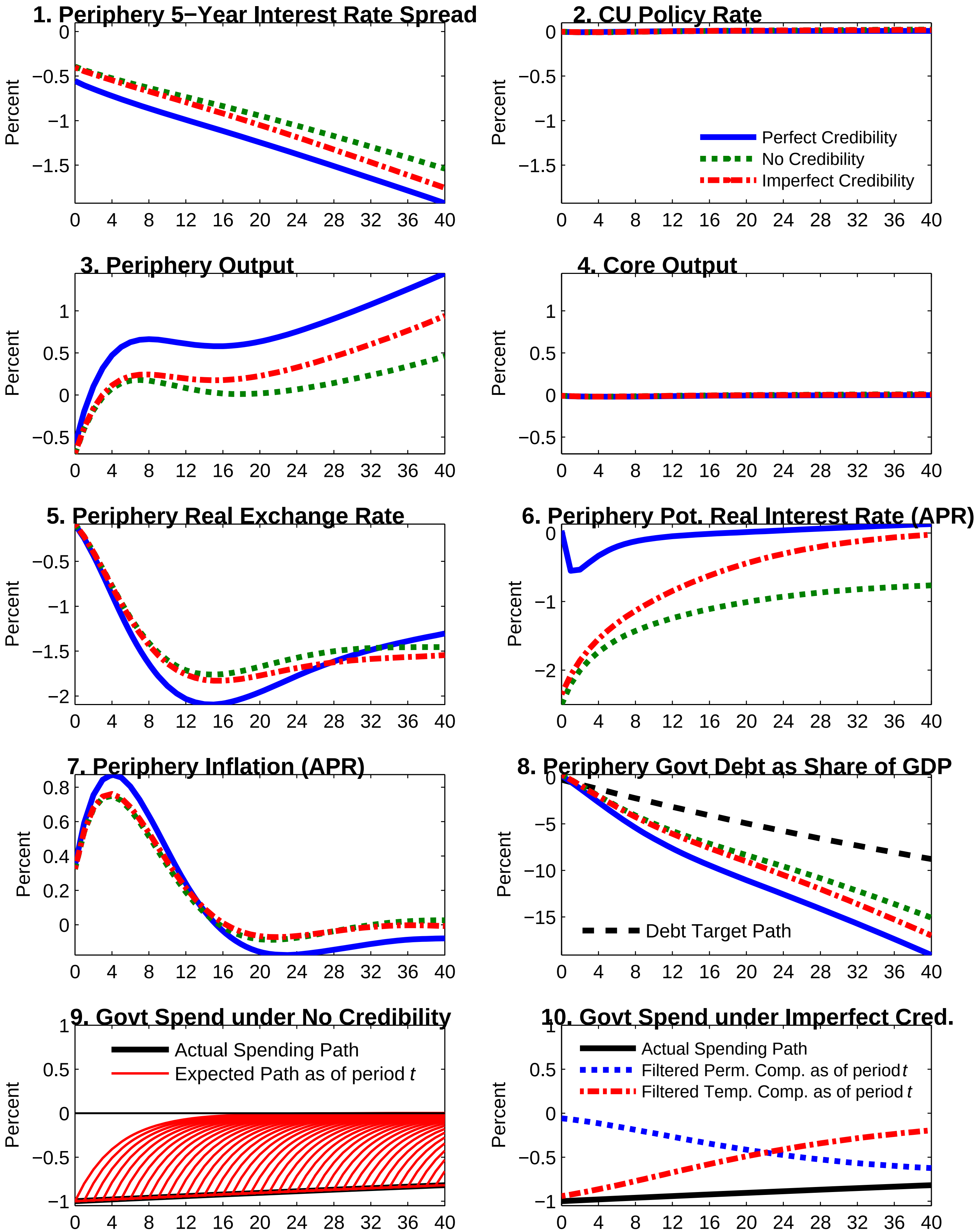
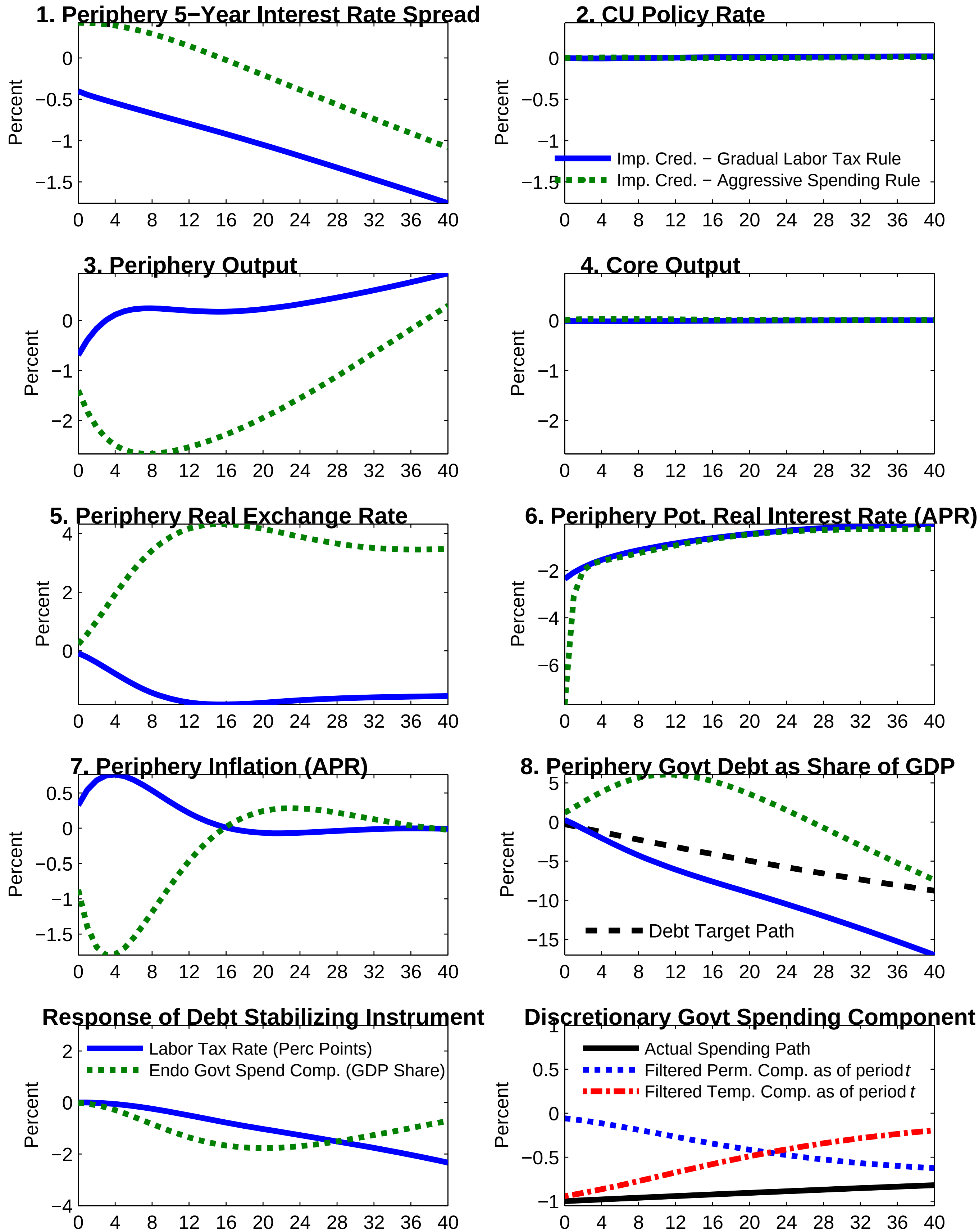


Figure 9: Fiscal Consolidation In Large Scale Model In Small CU Member With Endogenous Int. Rate Spreads: Aggressive Spending vs. Gradual Tax Debt Rule.



Appendix A The Large-Scale Open Economy Model

Following Erceg and Lindé (2013), this appendix contains a complete description of the large-scale model used in Section 4.

As the recent recession has provided strong evidence in favor of the importance of financial frictions, our model also features a financial accelerator channel which closely parallels earlier work by Bernanke, Gertler, and Gilchrist (1999) and Christiano, Motto, and Rostagno (2008). Given that the mechanics underlying this particular financial accelerator mechanism are well-understood, we simplify our exposition by focusing on a special case of our model which abstracts from a financial accelerator. We conclude our model description with a brief description of how the model is modified to include the financial accelerator (Section A.6).

A.1 Firms and Price Setting

We start by describing the production side of the model, including the modeling of slow price adjustment.

A.1.1 Production of Domestic Intermediate Goods

There is a continuum of differentiated intermediate goods (indexed $i \in [0, 1]$) in the Periphery, each of which is produced by a single monopolistically competitive firm. In the domestic market, firm i faces a demand function that varies inversely with its output price $P_{Dt}(i)$ and directly with aggregate demand at home Y_{Dt}, i.e.

$$Y_{Dt}(i) = \left[\frac{P_{Dt}(i)}{P_{Dt}}\right]^{\frac{-(1+\theta_p)}{\theta_p}} Y_{Dt}, \tag{A.1}$$

where $\theta_p > 0$, and P_{Dt} is an aggregate price index defined below. Similarly, firm i faces the following export demand function:

$$X_t(i) = \left[\frac{P^*_{Mt}(i)}{P^*_{Mt}}\right]^{\frac{-(1+\theta_p)}{\theta_p}} M^*_t, \tag{A.2}$$

where $X_t(i)$ denotes the quantity demanded of domestic good i in the Core block, $P^*_{Mt}(i)$ denotes the price that firm i sets in the Core market, P^*_{Mt} is the import price index in the

Core, and M_t^* is an aggregate of the Core's imports (we use an asterisk to denote the Core's variables).

Each producer utilizes capital services $K_t(i)$ and a labor index $L_t(i)$ (defined below) to produce its respective output good. The production function is assumed to have a constant-elasticity of substitution (CES) of the form

$$Y_t(i) = \left(\omega_K^{\frac{\rho}{1+\rho}} K_t(i)^{\frac{1}{1+\rho}} + \omega_L^{\frac{\rho}{1+\rho}} (Z_t L_t(i))^{\frac{1}{1+\rho}}\right)^{1+\rho}. \tag{A.3}$$

The production function exhibits constant-returns-to-scale in both inputs, and Z_t is a country-specific shock to the level of technology. Firms face perfectly competitive factor markets for hiring capital and labor. Thus, each firm chooses $K_t(i)$ and $L_t(i)$, taking both the rental price of capital R_{Kt} and the aggregate wage index W_t (defined below) as given. Firms can adjust either factor of production without costs, implying that each firm has an identical marginal cost per unit of output, MC_t. The (log-linearized) technology shock is assumed to follow an AR(1)-process:

$$z_t = \rho_z z_{t-1} + \varepsilon_{z,t}. \tag{A.4}$$

We assume that purchasing power parity holds, so that each intermediate goods producer sets the same price $P_{Dt}(i)$ in both blocks of the currency union, implying that $P_{Mt}^*(i) = P_{Dt}(i)$ and that $P_{Mt}^* = P_{Dt}$. The prices of the intermediate goods are determined by Calvo-style staggered contracts (see Calvo, 1983). In each period, a firm faces a constant probability, $1 - \xi_p$, of being able to re-optimize its price $P_{Dt}(i)$. This probability is independent across firms and time. If a firm is not allowed to optimize its prices, we follow Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003), and assume that the firm must reset its home price as a weighted combination of the lagged- and steady-state-rate of inflation $P_{Dt}(i) = \pi_{t-1}^{\iota_p} \pi^{1-\iota_p} P_{Dt-1}(i)$ for the non-optimizing firms. This formulation allows for structural persistence in price-setting if ι_p exceeds zero.

When a firm i is allowed to re-optimize its price in period t, the firm faces the following maximization problem:

$$\max_{P_{Dt}(i)} \mathbb{E}_t \sum_{j=0}^{\infty} \psi_{t,t+j} \xi_p^j \left[\prod_{h=1}^{j} \pi_{t+h-1} (P_{Dt}(i) - MC_{t+j})(Y_{Dt+j}(i) + X_t(i))\right]. \tag{A.5}$$

The operator $\mathbb{E}_t$ represents the conditional expectation based on the information available to agents at period t. The firm discounts profits received at date $t+j$ by the state-contingent discount factor $\psi_{t,t+j}$. For notational simplicity, we have suppressed all of the state indices.[A.1] The first-order condition for setting the contract price of good i is:

$$\mathbb{E}_t \sum_{j=0}^{\infty} \psi_{t,t+j} \xi_p^j \left(\frac{\prod_{h=1}^{j} \pi_{t+h-1}(i)\, P_{Dt}(i)}{(1+\theta_p)} - MC_{t+j} \right) (Y_{Dt+j}(i) + X_t(i)) = 0. \tag{A.6}$$

A.1.2 Production of the Domestic Output Index

Because households have identical Dixit-Stiglitz preferences, it is convenient to assume that a representative aggregator combines the differentiated intermediate products into a composite home-produced good

$$Y_{Dt} = \left[\int_0^1 Y_{Dt}(i)^{\frac{1}{1+\theta_p}} \, di \right]^{1+\theta_p}. \tag{A.7}$$

The aggregator chooses the bundle of goods that minimizes the cost of producing Y_{Dt}, taking the price $P_{Dt}(i)$ of each intermediate good $Y_{Dt}(i)$ as given. The aggregator sells units of each sectoral output index at its unit cost:

$$P_{Dt} = \left[\int_0^1 P_{Dt}(i)^{\frac{-1}{\theta_p}} \, di \right]^{-\theta_p}. \tag{A.8}$$

We also assume a representative aggregator in the Core who combines the differentiated Periphery products $X_t(i)$ into a single index for foreign imports:

$$M_t^* = \left[\int_0^1 X_t(i)^{\frac{1}{1+\theta_p}} \, di \right]^{1+\theta_p}, \tag{A.9}$$

and sells M_t^* at price P_{Dt}.

A.1.3 Production of Consumption and Investment Goods

Final consumption goods consumed by both households and the public sector are produced by a representative consumption goods distributor. This firm combines purchases

[A.1] We define $\xi_{t,t+j}$ to be the price in period t of a claim that pays one dollar if the specified state occurs in period $t+j$ (see the household problem below). The corresponding element of $\psi_{t,t+j}$ equals $\xi_{t,t+j}$ divided by the probability that the specified state will occur.

of domestically-produced goods with imported ones to produce a final consumption good C_{At} according to a constant-returns-to-scale CES production function:

$$C_{At} = \left(\omega_C^{\frac{\rho_C}{1+\rho_C}} C_{Dt}^{\frac{1}{1+\rho_C}} + (1-\omega_C)^{\frac{\rho_C}{1+\rho_C}} (\varphi_{Ct} M_{Ct})^{\frac{1}{1+\rho_C}} \right)^{1+\rho_C}, \tag{A.10}$$

where C_{Dt} denotes the consumption good distributor's demand for the index of domestically-produced goods, M_{Ct} denotes the distributor's demand for the index of foreign-produced goods, and φ_{Ct} reflects costs of adjusting consumption imports. The final consumption good is used by both households and by the government. The form of the production function mirrors the preferences of households and the government sector over consumption of domestically-produced goods and imports. Accordingly, the quasi-share parameter ω_C may be interpreted as determining the preferences of both the private and public sector for domestic relative to foreign consumption goods, or equivalently, the degree of home bias in consumption expenditure. Finally, the adjustment cost term φ_{Ct} is assumed to take the quadratic form:

$$\varphi_{Ct} = \left[1 - \frac{\varphi_{M_C}}{2} \left(\frac{\frac{M_{Ct}}{C_{Dt}}}{\frac{M_{Ct-1}}{C_{Dt-1}}} - 1 \right)^2 \right]. \tag{A.11}$$

This specification implies that it is costly to change the proportion of domestic and foreign goods in the aggregate consumption bundle, even though the level of imports may jump – without costs – in response to changes in overall consumption demand.

Given the presence of adjustment costs, the representative consumption goods distributor chooses (a contingency plan for) C_{Dt} and M_{Ct} to minimize its discounted expected costs of producing the aggregate consumption good:

$$\begin{aligned} &\min_{C_{Dt+k}, M_{Ct+k}} \mathbb{E}_t \sum_{k=0}^{\infty} \psi_{t,t+k} \Bigg\{ (P_{Dt+k} C_{Dt+k} + P_{Mt+k} M_{Ct+k}) + \\ &P_{Ct+k} \left[C_{A,t+k} - \left(\omega_C^{\frac{\rho_C}{1+\rho_C}} C_{Dt+k}^{\frac{1}{1+\rho_C}} + (1-\omega_C)^{\frac{\rho_C}{1+\rho_C}} (\varphi_{Ct+k} M_{Ct+k})^{\frac{1}{1+\rho_C}} \right)^{1+\rho_C} \right] \Bigg\}. \end{aligned} \tag{A.12}$$

The distributor sells the final consumption good to households and the government at a price P_{Ct}, which may be interpreted as the consumption price index (or equivalently, as the shadow cost of producing an additional unit of the consumption good).

We model the production of final investment goods in an analogous manner, although we allow the weight ω_I in the investment index to differ from that of the weight ω_C in the consumption goods index.[A.2]

A.2 Households and Wage Setting

We assume a continuum of monopolistically competitive households (indexed on the unit interval), each of which supplies a differentiated labor service to the intermediate goods-producing sector (the only producers demanding labor services in our framework), following Erceg, Henderson, and Levin (2000). A representative labor aggregator (or "employment agency") combines households' labor hours in the same proportions as firms would choose. Thus, the aggregator's demand for each household's labor is equal to the sum of firms' demands. The aggregate labor index L_t has the Dixit-Stiglitz form:

$$L_t = \left[\int_0^1 \left(\zeta N_t \left(h \right) \right)^{\frac{1}{1+\theta_w}} dh \right]^{1+\theta_w}, \tag{A.13}$$

where $\theta_w > 0$, and $N_t(h)$ is hours worked by a typical member of household h. The parameter ζ is the size of a household of type h, and effectively determines the size of the population in the Periphery. The aggregator minimizes the cost of producing a given amount of the aggregate labor index, taking each household's wage rate $W_t\left(h\right)$ as given, and then sells units of the labor index to the production sector at their unit cost W_t:

$$W_t = \left[\int_0^1 W_t \left(h \right)^{\frac{-1}{\theta_w}} dh \right]^{-\theta_w}. \tag{A.14}$$

The aggregator's demand for the labor services of a typical member of household h is given by

$$N_t \left(h \right) = \left[\frac{W_t \left(h \right)}{W_t} \right]^{-\frac{1+\theta_w}{\theta_w}} L_t / \zeta. \tag{A.15}$$

We assume that there are two types of households: households that make intertemporal consumption, labor supply, and capital accumulation decisions in a forward-looking manner by maximizing utility subject to an intertemporal budget constraint (FL-households, for "forward-looking"); and the remainder that simply consume their disposable income. The latter type receive no rental income or profits, and choose to set their wage to be the average of optimizing households. We denote the share of FL-households by $1 - \varsigma$ and the share of HM-households by ς.

[A.2] Note that the final investment good is not used by the government.

We first consider the problem faced by FL-households. The utility function for an optimizing representative from household h is

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma} \left(C^O_{t+j}(h) - \varkappa C^O_{t+j-1} - \nu_{ct} \right)^{1-\sigma} + \frac{\chi_0 Z^{1-\sigma}_{t+j}}{1-\chi} (1 - N_{t+j}(h))^{1-\chi} + \mu_0 F\left(\frac{MB_{t+j+1}(h)}{P_{Ct+j}} \right) \right\}, \tag{A.16}$$

where the discount factor β satisfies $0 < \beta < 1$. As did Smets and Wouters (2003, 2007), we allow for the possibility of external habit formation in preferences, so that each household member cares about its consumption relative to lagged aggregate consumption per capita of forward-looking agents C^O_{t-1}. The period utility function depends on each member's current leisure $1-N_t(h)$, end-of-period real money balances $\frac{MB_{t+1}(h)}{P_{Ct}}$, and a preference shock ν_{ct}. The sub-utility function $F(\cdot)$ over real balances is assumed to have a satiation point to account for the possibility of a zero nominal interest rate. Eggertsson and Woodford (2003) discusses this content further.[A.3] The (log-linearized) consumption demand shock ν_{ct} is assumed to follow an AR(1)-process:

$$\nu_{ct} = \rho_\nu \nu_{ct-1} + \varepsilon_{\nu_c,t.} \tag{A.17}$$

Forward-looking household h faces a flow budget constraint in period t which states that its combined expenditure on goods and on the net accumulation of financial assets must equal its disposable income:

$$\begin{aligned} &P_{Ct}(1+\tau_{Ct}) C^O_t(h) + P_{It} I_t(h) + MB_{t+1}(h) - MB_t(h) + \int_s \xi_{t,t+1} B_{Dt+1}(h) \\ &- B_{Dt}(h) + P_{Bt} B_{Gt+1} - B_{Gt} + \tfrac{P^*_{Bt} B_{Ft+1}(h)}{\phi_{bt}} - B_{Ft}(h) \\ &= \\ &(1-\tau_{Nt}) W_t(h) N_t(h) + \Gamma_t(h) + TR_t(h) + (1-\tau_{Kt}) R_{Kt} K_t(h) + \\ &P_{It} \tau_{Kt} \delta K_t(h) - P_{Dt} \phi_{It}(h). \end{aligned} \tag{A.18}$$

Consumption purchases are subject to a sales tax of τ_{Ct}. Investment in physical capital augments the per capita capital stock $K_{t+1}(h)$ according to a linear transition law of the form:

$$K_{t+1}(h) = (1-\delta) K_t(h) + I_t(h), \tag{A.19}$$

where δ is the depreciation rate of capital.

[A.3] For simplicity, we assume that μ_0 is sufficiently small such that changes in the monetary base have a negligible impact on equilibrium allocations, at least to the first-order approximation which we consider.

Financial asset accumulation of a typical member of FL-household h consists of increases in nominal money holdings $(MB_{t+1}(h) - MB_t(h))$ and the net acquisition of bonds. While the domestic financial market is complete through the existence of state-contingent bonds B_{Dt+1}, cross-border asset trade is restricted to a single non-state contingent bond issued by the government of the Core economy.[A.4]

The terms B_{Gt+1} and B_{Ft+1} respectively represents each household member's net purchases of the government bonds issued by the Periphery and Core governments. Each type of bond pays one currency unit (e.g., euro) in the subsequent period, and is sold at a (discounted) price of P_{Bt} and P_{Bt}^*, respectively. To ensure the stationarity of foreign asset positions, we follow Turnovsky (1985) by assuming that domestic households must pay a transaction cost when trading in the foreign bond. The intermediation cost depends on the ratio of economy-wide holdings of net foreign assets to nominal GDP, P_tY_t, and is given by

$$\phi_{bt} = \exp\left(-\phi_b\left(\frac{B_{Ft+1}}{P_tY_t}\right)\right). \tag{A.20}$$

If the Periphery posits an overall net lender position internationally, then a household will earn a lower return on any holdings of foreign (i.e., Core) bonds. By contrast, if the Periphery has a net debtor position, a household will pay a higher return on its foreign liabilities. Given that the domestic government- and the foreign-bond have the same payoff, the price faced by domestic residents net of the transaction cost is identical, so that $P_{Bt} = \frac{P_{Bt}^*}{\phi_{bt}}$. The effective nominal interest rate on domestic bonds (and similarly for foreign bonds) hence equals $i_t = 1/P_{Bt} - 1$.

Each member of FL-household h earns net labor income $(1-\tau_{Nt})W_t(h)N_t(h)$, in which τ_{Nt} is a stochastic tax on labor income. The household leases capital at net rental rate $(1-\tau_{Kt})R_{Kt}$, where τ_{Kt} is a stochastic tax on capital income. The household receives a depreciation write-off of $P_{It}\tau_{Kt}\delta$ per unit of capital. Each member also receives an aliquot share $\Gamma_t(h)$ of the profits of all firms as well as a lump-sum government transfer $TR_t(h)$ (which is negative in the case of a tax). Following Christiano, Eichenbaum, and Evans (2005), we assume that it is costly to change the level of gross investment from the previous

[A.4] Note that the contingent claims B_{Dt+1} are in zero net supply from the standpoint of the Periphery as a whole.

period, so that the acceleration in the capital stock is penalized:

$$\phi_{It}(h) = \frac{1}{2}\phi_I \frac{(I_t(h) - I_{t-1})^2}{I_{t-1}}. \tag{A.21}$$

In every period t, each member of FL-household h maximizes the utility function in (A.16) with respect to consumption, investment, (end-of-period) capital stock, money balances, holdings of contingent claims, and holdings of domestic and foreign bonds, subject to its labor demand function in (A.15), budget constraint in (A.18), and transition equation for capital in (A.19). By doing so, a household takes prices as given, likewise taxes and transfers, and aggregate quantities such as lagged aggregate consumption and the aggregate net foreign asset position.

Forward-looking (FL) households set nominal wages in staggered contracts that are analogous to the price contracts described above. In particular, with probability $1 - \xi_w$, each member of a household is allowed to re-optimize its wage contract. If a household is not allowed to optimize its wage rate, we assume each household member to reset its wage according to:

$$W_t(h) = \omega_{t-1}^{\iota_w}\omega^{1-\iota_w}W_{t-1}(h), \tag{A.22}$$

where ω_{t-1} is the gross nominal wage inflation in period $t-1$, i.e. W_t/W_{t-1}, and $\omega = \pi$ is the steady state rate of change in the nominal wage (equal to gross price inflation since steady state gross productivity growth is assumed to be unity). Dynamic indexation of this form introduces some element of structural persistence into the wage-setting process. Each member of household h chooses the value of $W_t(h)$ to maximize the utility function in (A.16) subject to these constraints.

Finally, we consider the determination of consumption and labor supply of the HM-households. A typical member of a HM-household simply equates nominal consumption spending $P_{Ct}(1+\tau_{Ct})C_t^{HM}(h)$ to current disposable income, which consists of after-tax labor income plus lump-sum transfers from the government:

$$P_{Ct}(1+\tau_{Ct})C_t^{HM}(h) = (1-\tau_{Nt})W_t(h)N_t(h) + TR_t(h). \tag{A.23}$$

The HM-households are assumed to set their wage equal to the average of the FL-households. Since HM-households face the same labor demand schedule as does the FL-ones, this assumption implies that each HM household works the same number of hours as the average of FL-households.

A.3 Monetary Policy

We assume that the central bank follows a Taylor rule for setting the policy rate of the currency union, subject to the zero bound constraint on nominal interest rates. Thus:

$$i_t = \max\left\{-i, (1-\gamma_i)\left(\tilde{\pi}_t + \gamma_\pi(\tilde{\pi}_t - \pi) + \gamma_x \tilde{x}_t\right) + \gamma_i i_{t-1}\right\}. \tag{A.24}$$

In this equation, i_t is the quarterly nominal interest rate expressed in deviation from its steady state value of i. Hence, imposing the zero lower bound implies that i_t cannot fall below $-i$. The price inflation rate of the currency union is denoted by $\tilde{\pi}_t$, π denotes the inflation target, and $\tilde{x}_t$ is the output gap of the currency union. The aggregate inflation and output-gap measures are defined as a GDP-weighted average of the inflation rates and output gaps of the Periphery and Core. Finally, the output gap in each member is defined as the deviation of actual output from its potential level, where potential is the level of output that would prevail if wages and prices were completely flexible.

A.4 Fiscal Policy

The government does not need to balance its budget each period, and issues nominal debt B_{Gt+1} at the end of period t to finance its deficits according to:

$$\begin{aligned} P_{Bt}B_{Gt+1} - B_{Gt} &= P_{Ct}G_t + TR_t - \tau_{Nt}W_tL_t - \tau_C P_{Ct}C_t - (\tau_K R_{Kt} - \delta P_{It})K_t \\ &\quad -(MB_{t+1} - MB_t), \end{aligned} \tag{A.25}$$

where C_t is total private consumption. Equation (A.25) aggregates the capital stock, money and bond holdings, and transfers and taxes over all households so that, for example, $TR_t = \int_0^1 TR_t(h)dh$. The taxes on capital τ_K and consumption τ_C are assumed to be fixed, and so is the ratio of real transfers to trend GDP, $tr = \frac{TR_t}{P_tY}$.[A.5] Government purchases enters additively in household's period utility function and thus do not directly affect the decision of the household. Nor do they affect the production function of the private sector.

[A.5] Given that the central bank uses the nominal interest rate as its policy instrument, the level of seigniorage is determined by nominal money demand.

A.5 Resource Constraint and Net Foreign Assets

The domestic economy's aggregate resource constraint can be written as:

$$Y_{Dt} = C_{Dt} + I_{Dt} + \phi_{It}, \tag{A.26}$$

where ϕ_{It} is the adjustment cost on investment aggregated across all households. The final consumption good (see Equation A.10) is allocated between households and the government:

$$C_{At} = C_t + G_t, \tag{A.27}$$

where C_t is total private consumption of FL- and HM-optimizing households:

$$C_t = C_t^O + C_t^{HM}. \tag{A.28}$$

Note that this setup implies that part of government consumption consist of imported goods. Total exports may be allocated to either the consumption or the investment sector abroad:

$$M_t^* = M_{Ct}^* + M_{It}^*. \tag{A.29}$$

Finally, at the level of the individual firm:

$$Y_t(i) = Y_{Dt}(i) + X_t(i), \qquad \forall i. \tag{A.30}$$

The evolution of net foreign assets can be expressed as:

$$\frac{P_{B,t}^* B_{F,t+1}}{\phi_{bt}} = B_{F,t} + P_{Mt}^* M_t^* - P_{Mt} M_t. \tag{A.31}$$

This expression can be derived from the budget constraint of the FL-households after imposing the government budget constraint, the consumption rule of the HM-households, the definition of firm profits, and the condition that domestic state-contingent non-government bonds B_{Dt+1} are in zero net supply.

Finally, we assume that the structure of the foreign country (the Core) is isomorphic to that of the home country (the Periphery).

A.6 Production of Capital Services

We incorporate a financial accelerator mechanism into both country blocks of our benchmark model following the basic approach of Bernanke, Gertler, and Gilchrist (1999). Thus, the intermediate goods producers rent capital services from entrepreneurs (at the price R_{Kt}) rather than directly from households. Entrepreneurs purchase physical capital from competitive capital goods producers (and resell it back at the end of each period), with the latter employing the same technology to transform investment goods into finished capital goods as described by Equations (A.19) and (A.21). To finance the acquisition of physical capital, each entrepreneur combines the net worth with a loan from a bank, for which the entrepreneur must pay an external finance premium (over the risk-free interest rate set by the central bank) due to an agency problem. Banks obtain funds to lend to the entrepreneurs by issuing deposits to households at the interest rate set by the central bank, with households bearing no credit risk (reflecting assumptions about free competition in banking and the ability of banks to diversify their portfolios). In equilibrium, shocks that affect entrepreneurial net worth, i.e., the leverage of the corporate sector, induce fluctuations in the corporate finance premium.[A.6]

A.7 Calibration of Parameters

Here we report calibration of the parameters not discussed in the main text.

We assume that the discount factor $\beta = 0.995$, consistent with a steady-state annualized real interest rate $\bar{r}$ of 2 percent. By assuming that gross inflation $\pi = 1.005$ (i.e. a net inflation of 2 percent in annualized terms), the implied steady state nominal interest rate i equals 0.01 at a quarterly rate, and 4 percent at an annualized rate.

The utility function parameter σ is set equal to 1 to ensure that the model exhibit balanced growth, while the parameter determining the degree of habit persistence in consumption $\varkappa = 0.8$. We set $\chi = 6$, implying a Frisch elasticity of labor supply of one third,

[A.6] We follow Christiano, Motto and Rostagno (2008) by assuming that the debt contract between entrepreneurs and banks is written in nominal terms [rather than real terms as Bernanke, Gertler, and Gilchrist, (1999)]. For further details about the setup, see Bernanke, Gertler, and Gilchrist (1999), and Christiano, Motto, and Rostagno (2008). An excellent exposition is also provided by Christiano, Trabandt, and Walentin (2007).

which is in the mid-range of empirical estimates reported by Domeij and Flodén (2006). The utility parameter χ_0 is set so that employment comprises one-third of the household's time endowment, while the parameter μ_0 on the sub-utility function for real balances is set at an arbitrarily low value (so that variation in real balances do not affect equilibrium allocations). We set the share of HM agents $\varsigma = 0.50$, implying that these agents account for about $1/3$ of aggregate private consumption spending (the latter is smaller than the population share of HM-agents because the latter own no capital).

The depreciation rate of capital δ is set at 0.03 (consistent with an annual depreciation rate of 12 percent). The parameter ρ in the CES-production function of the intermediate goods producers is set to -2, implying an elasticity of substitution between capital and labor $(1+\rho)/\rho$, of $1/2$. The quasi-capital share parameter ω_K – together with the price markup parameter of $\theta_P = 0.20$ – is chosen to imply a steady state investment to output ratio of 15 percent. We set the cost of adjusting investment parameter $\phi_I = 3$, slightly below the value estimated by Christiano, Eichenbaum, and Evans (2005). The calibration of the parameters determining the financial accelerator follows Bernanke, Gertler, and Gilchrist (1999). In particular, the monitoring cost μ expressed as a proportion of entrepreneurs' total gross revenue, is set to 0.12. The default rate of entrepreneurs is three percent per year, and the variance of the idiosyncratic productivity shocks to entrepreneurs is 0.28.

Our calibration of the parameters of the monetary policy rule and the Calvo price, and wage contract duration parameters – while within the range of empirical estimates – tilt in the direction of reducing the sensitivity of inflation to shocks. These choices seems reasonable given the resilience of inflation in most euro area countries in the aftermath of the global financial crisis. In particular, we set the parameters of the monetary rule such that $\gamma_\pi = 1.5$, $\gamma_x = 0.125$, and $\gamma_i = 0.7$, implying a considerably larger response to inflation than a standard Taylor rule (which would set $\gamma_\pi = 0.5$). The price contract duration parameter ξ_p equals 0.9, and the price indexation parameter ι_p equals 0.65. Our choice of ξ_p implies a Phillips curve slope of about 0.007, which is a bit lower than the median estimates in the literature that cluster in the range of $0.009 - 0.014$, but well within the standard confidence intervals provided by empirical studies [see e.g. Adolfson et al. (2005), Altig et al. (2010), Galí and Gertler (1999), Galí, Gertler, and López-Salido (2001), Lindé (2005), and Smets and

Wouters (2003, 2007)]. Our chosen wage markup of $\theta_W = 1/3$, contract duration parameter of $\xi_w = 0.85$, and wage indexation parameter $\iota_w = 0.65$, together implies that wage inflation is somewhat less responsive ($\kappa_w = .002$) to the wage markup than price inflation is to the price markup ($\kappa_{mc} = .011$).[A.7]

We assume that $\rho_C = \rho_I = 2$, which is consistent with a long-run price elasticity of demand for imported consumption and investment goods of 1.5. The adjustment cost parameters are set so that $\varphi_{M_C} = \varphi_{M_I} = 1$, which slightly damps the near-term relative price sensitivity.

[A.7] Given strategic complementarity in wage-setting, the wage-markup influences the slope of the wage Phillips Curve.

Appendix B Results in Large Scale Model with Faster Wage and Price Adjustment

In this appendix, we examine to which extent the results in Figure 7 changes when we allow for faster wage adjustment (see Figure B.1) and faster adjustment of both wages and prices (Figure B.2).

B.1 Faster Wage Adjustment

In the benchmark calibration of our model, we assume a wage contract duration parameter of $\xi_w = 0.85$, which implies that nominal wage inflation is less responsive to the wage markup than price inflation is to the price markup. We now entertain an alternative calibration where nominal wage inflation is equally responsive to the wage markup, which we achieve by changing ξ_w to 0.70. Assuming that wages are more flexible than in our benchmark calibration can be rationalized by the fact that unit labor costs have indeed fallen markedly in all peripheral EA-countries (except Italy) relative to other EA-economies, inflation outcomes have remained in line with overall EA-inflation (as shown in Figure 1). Estimation results of Blanchard, Erceg, and Lindé (2016), who estimate the degree of wage and price stickiness by matching the impulse response functions to monetary policy and government spending shocks of the model with that of a structural VAR, also supports the notion that ξ_w is lower than entertained in our benchmark calibration.

The results with this alternative settings for exactly the same experiments as depicted in Figure 7 are reported in Table B.1. By comparing the results in Figures B.1 with those in Figure 7, we see that the results from a qualitative perspective are virtually unchanged. Even from a quantitative perspective, the results are very little affected. We thereby conclude that the results are not much impacted when varying the speed of wage adjustment within reasonable bounds.

B.2 Faster Wage and Price Adjustment

Although we believe unconditional data evidence (Figure 1) and conditional data evidence (estimation results in DSGEs and structural vector autoregressive models) does not support faster price adjustment, we report results in Figure B.2 for a variant of our model with both faster wage and price adjustment, which we achieve by setting ξ_w to .70 – as in Figure B.2 – and lowering ξ_p from .90 to .80. This is a sizable change in the degree of stickiness, and the partial impact of the faster price adjustment can be teased out by comparing the results in Figure B.1 with ones in Figure B.2. By comparing the results in Figure B.2 with the benchmark results in Figure 7, we get an assessment of the overall impact of both faster wage and price adjustment.

Whereas the results in Figure B.1 were little changed relative to our benchmark results in Figure 7, the message from Figure B.2 is that although the results are qualitatively similar, they differ markedly quantitatively. In particular, with both faster wage and price adjustment, the macroeconomic costs of impaired credibility are notably smaller. For instance, after 10 years GDP falls 1.1 percent in the no-credibility-case after 10 years in our benchmark calibration (see Figure 7). With faster price- and wage-adjustment, the corresponding number in Figure B.2 is -0.8 percent. Under perfect credibility, however, the drop in output is roughly the same under both calibrations (-0.6 percent).

Hence, a substantial share of the differences between the perfect and imperfect credibility cases are accounted for by slow price adjustment. However, provided that slow price adjustment is strongly supported by the data within a New Keynesian framework, we do not believe that this is a strong weakness of our paper. The results shown in Figure B.2 however, clearly indicates that sticky prices are an important feature which strengthens the importance of credibility.

B.3 Faster Price Adjustment but Slower Wage Adjustment

Finally, we present results and discuss the case when prices adjust quickly (lowering ξ_p from 0.90 to 0.80), but wage adjustment is slower (increasing ξ_w from 0.85 to 0.95). The results for this case are reported in Figure B.3.

As can be seen in Figure B.3, the effects of impaired credibility are sizable in this case, although price adjustment is quick. The reason is that wage adjustment is very sluggish in this model. This demonstrates that we only need either slow price or slow wage adjustment for our basic result to hold. We believe our benchmark calibration with relatively slow degree of price adjustment and faster wage adjustment makes most sense based on outcomes during the crisis, but believe Figure B.3 to be useful nevertheless as it helps us to understand what is needed in the workhorse model for the results to hold up.

Figure B.1: Fiscal Consolidation In Large Scale Model In Small CU Member: Allowing for Faster Adjustment in Wage−Setting.

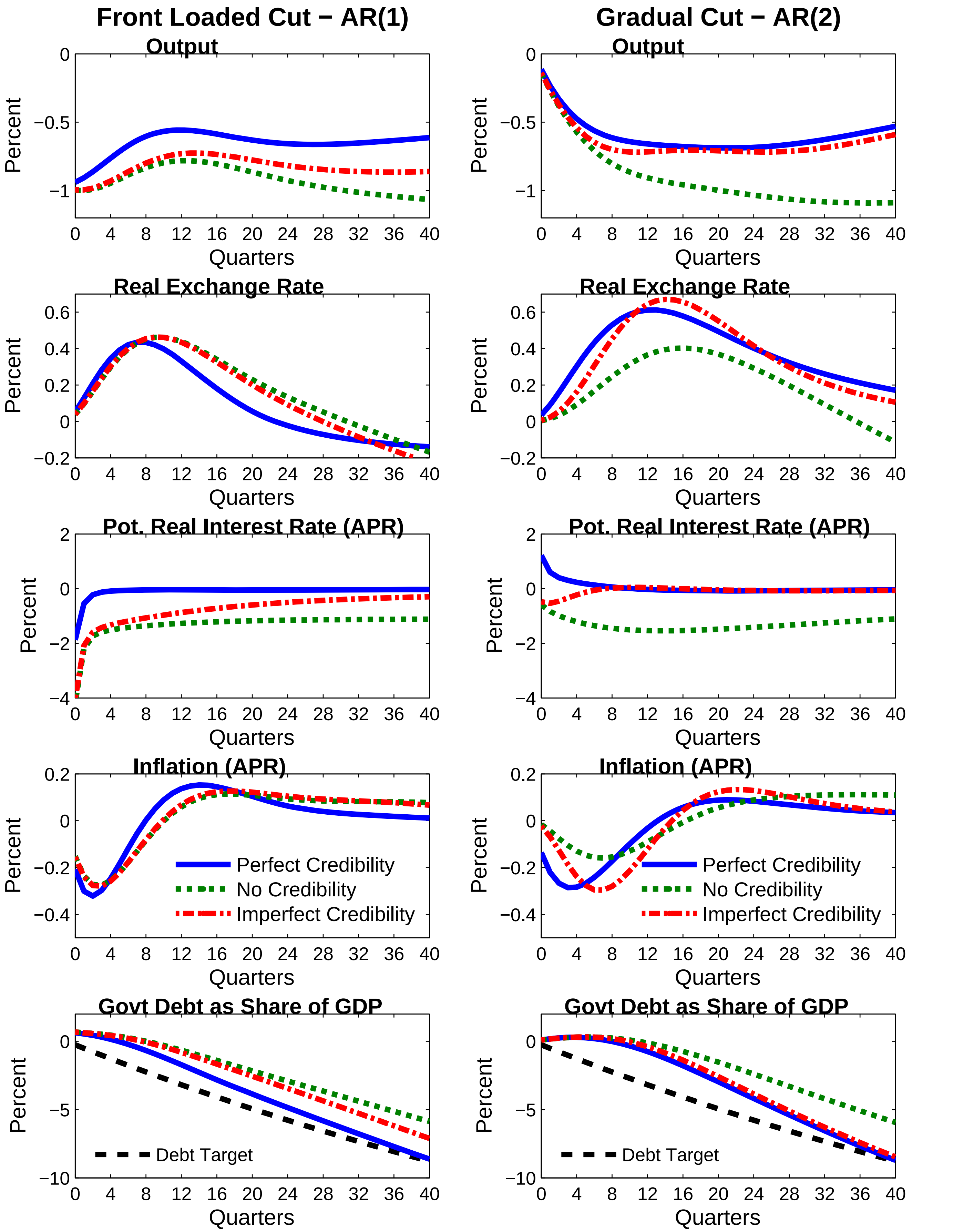


Figure B.2: Fiscal Consolidation In Large Scale Model In Small CU Member: Allowing for Faster Adjustment in Wage− and Price Setting.

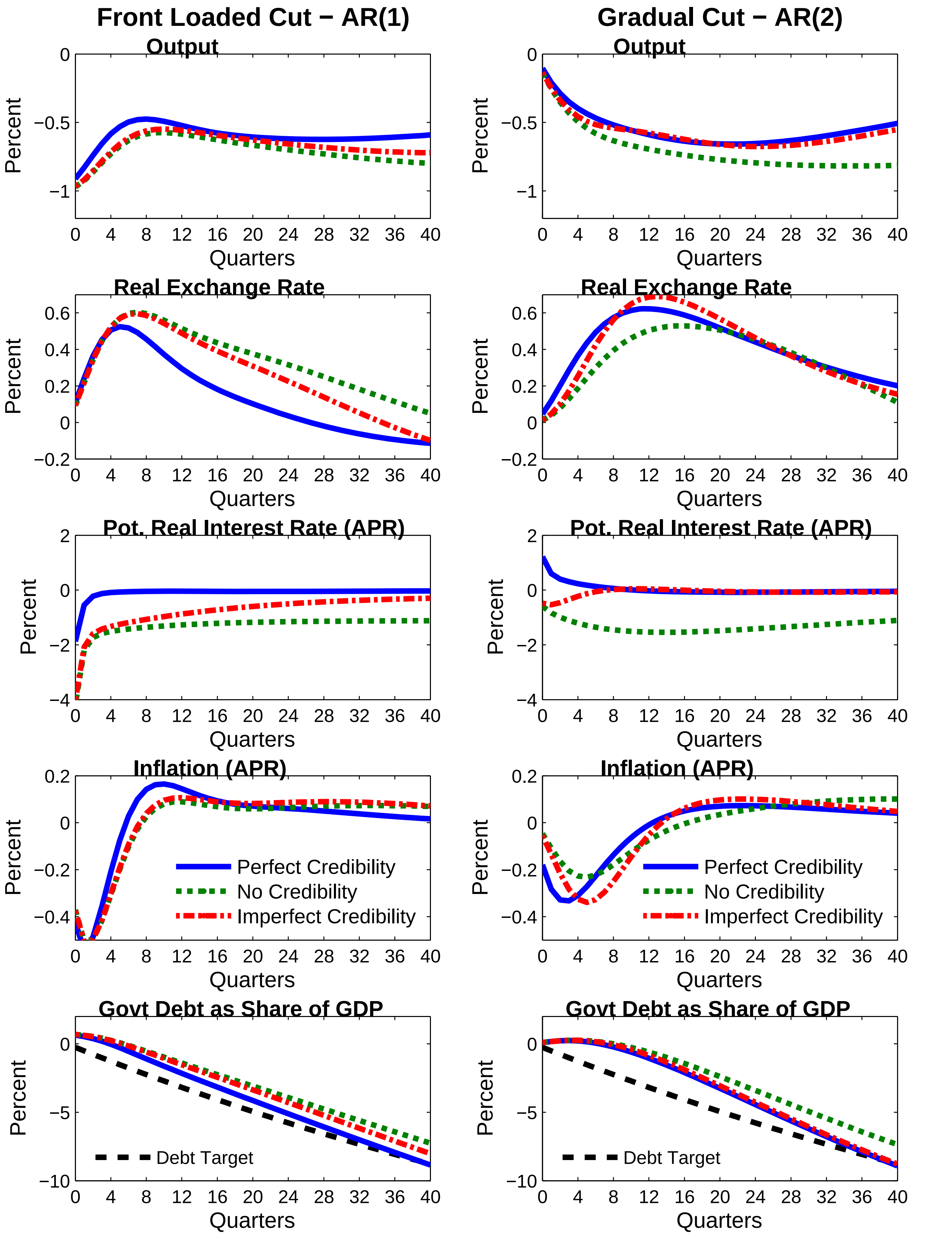
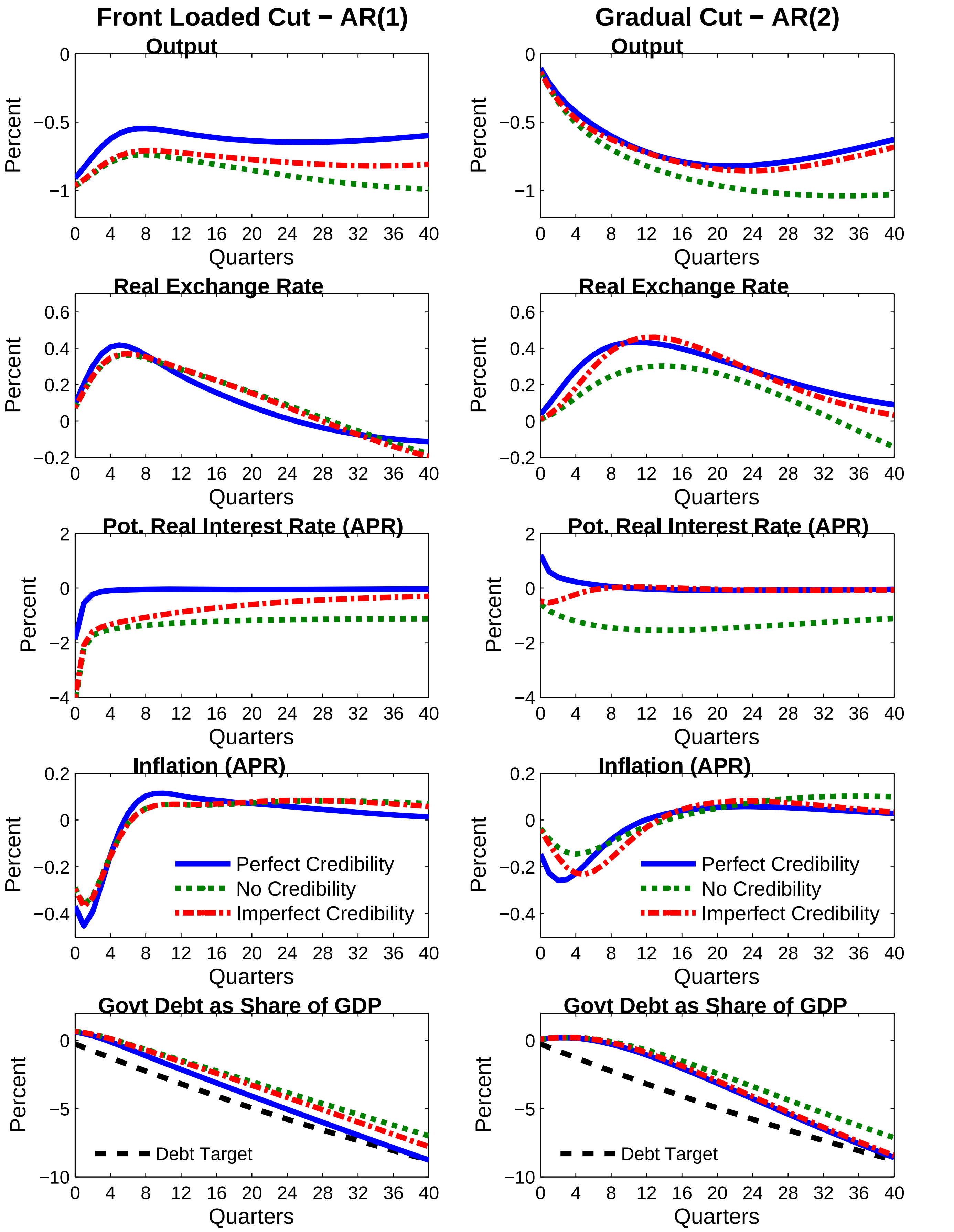


Figure B.3: Fiscal Consolidation In Large Scale Model In Small CU Member: Faster Adjustment in Price−Setting But Slower Wage Adjustment.



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