BANCA D'ITALIA

EUROSISTEMA

Temi di Discussione

(Working Papers)

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January 2015

Number 1002

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ISSN 1594-7939 (print)
ISSN 2281-3950 (online)

Printed by the Printing and Publishing Division of the Bank of Italy

STRUCTURAL REFORMS AND ZERO LOWER BOUND IN A MONETARY UNION

by Andrea Gerali*, Alessandro Notarpietro* and Massimiliano Pisani*

Abstract

We assess the short- and medium-term macroeconomic effects of competition-friendly reforms in the service sector when the monetary policy rate is stuck at the zero lower bound (ZLB) in a monetary union. We calibrate a large-scale multi-country multi-sector dynamic general equilibrium model to one region within the euro area, the rest of the euro area and the rest of the world. We find first, that unilateral reforms by a single country do not affect the number of periods for which the ZLB holds and have mild medium-term expansionary effects on GDP. Second, reforms simultaneously implemented in the entire euro area can favor an earlier exit from the ZLB if they have sufficiently inflationary effects, which happens when the gradual increase in the supply of goods and services is matched by a sufficiently large increase in investment, associated with higher expected levels of output. Reforms have expansionary effects because of their positive wealth effect, which more than counterbalances the recessionary substitution effect associated with higher real interest rates. If investment cannot immediately react to the reforms, then the latter has a deflationary impact and the duration of the ZLB is not reduced.

JEL Classification: C51, E31, E52.
Keywords: competition, markups, monetary policy, zero lower bound.

Contents

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1 Introduction[1]

The recent financial and economic crises pose serious challenges for the supply-side performance of several European countries. According to European Central Bank (2011), " The average rate of annual potential growth was estimated to be around 1.9% in the period 2000-07 [...] This compares with an average estimate of the annual rate of potential growth of 0.9% in the years 2008-10." Such challenges are further amplified by the historically poor supply-side performance of the European economy, characterized by lack of competition in the service sector and in general in those sectors sheltered from international competition.[2]

Long-run macroeconomic benefits of structural reforms are clear and well documented in the literature.[3] To the opposite, their short-run macroeconomic effects are less clear, as they heavily depend on monetary policy. In particular, two issues arise when the reforms in the euro area (EA) are considered. First, the monetary policy rate responds to the main EA-wide variables. From this perspective, it could make a difference if reforms are implemented by one country apart or simultaneously by several country members. Second, the monetary policy rate could be constrained by the zero lower bound (ZLB). The monetary authority would not be able to reduce the interest rate if this were consistent with the effects of the reforms. In this case, the real interest rate could increase as the reforms would reduce inflation and the monetary authority cannot lower the policy rate. The reforms could have negative macroeconomic effects on the country or the whole EA.

In this paper we assess the short and medium-run macroeconomic effects of reforms aimed at permanently increasing competition in the EA service sector when the ZLB holds. The assessment is based on simulating a three-country large scale new-Keynesian dynamic general equilibrium model of a generic EA country member (labelled "Home"), the rest of the euro area (REA) and the rest of the world (RW) economy, akin to the Eurosystem EAGLE (Euro Area and Global Economy model, see Gomes et al., 2010).[4] The EA economy is a two-region monetary union and therefore is characterized by a common monetary policy and nominal exchange rate against the RW block (the latter has its own monetary policy and currency). The model features monopolistic competition in intermediate product markets. It is formalized by a markup of prices over the marginal cost. The markup is inversely related to the degree of substitutability across product and labor varieties, and hence the underlying level of competition. Given the presence of nontradables, we can analyze the effects of increasing the degree of competition in

[1]The views expressed in this paper are those of the authors alone and should not be attributed to the Bank of Italy. We thank Giuseppe Ferrero, Alberto Locarno, an anonymous referee and participants at the Computing in Economics and Finance 2014 Conference.

[2]For example, according to the Europe 2020 Strategy "raising taxes on labour, as has occurred in the past at great costs to jobs, should be avoided. Rather Member States should seek to shift the tax burden from labour to energy and environmental taxes". See European Commission (2010).

[3]See, among the others, Forni et al. (2010a) and Gomes et al. (2013).

[4]See also the Global Economic Model developed at the International Monetary Fund (see Laxton and Pesenti 2003 and Pesenti 2008) and the New Area Wide Model developed at the European Central Bank (see Christoffel et al., 2008).

the service sectors, traditionally considered as mainly nontradable. Finally, the inclusion of the RW allows for a full characterization of trade flows. Intermediate tradeable and nontradable goods are produced according to a constant-elasticity-of-substitution (CES) production function that includes labor and physical capital. Both factors are supplied by domestic households. Short-run dynamics is determined by standard adjustment costs on nominal prices and wages, consumption and investment.

All simulations are run under the assumption of perfect foresight. As such, reforms are fully credible, there is no uncertainty, households and firms anticipate the transition paths and the final equilibria.

We initially simulate a negative persistent (demand) shock to worldwide private consumption and investment, lasting for three years. Because of the shock, the EA monetary policy rate immediately hits the ZLB and stays at that level for 7 quarters. Thereafter, it gradually increases and reduces the negative difference with respect to its baseline level, as EA inflation and gross domestic product (GDP) growth return to their corresponding baseline values. On top of this scenario, we initially simulate that the (gross) markup in the Home nontradable sector is gradually reduced by 10 percentage points over a 5 year-period. The effects of the reform are evaluated first under the assumption of unilateral implementation in the Home country. Subsequently, we assume that the reform is implemented simultaneously in the EA as a whole.

Our results are as follows. First, reforms implemented unilaterally by one country apart mildly reduce, after one year, the recessionary effect on GDP and do not affect the number of periods for which the ZLB holds. Second, reforms implemented in both EA regions can favour an earlier exit from the ZLB if they induce a lower decrease in inflation. This is the case if the gradual increase in the supply of goods and services is matched by a sufficiently large increase in aggregate demand for investment, associated with the anticipation of a permanent increase in long-run production. If the reforms are suddenly implemented, then the length of the ZLB is not reduced. If, in addition, investment cannot react, then the deflationary impact of the reforms is largely magnified. The latter case can approximate a situation in which firms are financially constrained and face limits in credit supply. As such, the higher demand for investment induced by the reforms in the service sector cannot be adequately financed and, therefore, new capital cannot be accumulated to meet the expected higher levels of production. As a result, aggregate demand responds less and the length of the ZLB is not affected. Finally, results are robust to alternative assumptions on key parameters.

Our paper is related to several contributions existing in the literature. Forni et al. (2010a, b) evaluate the macroeconomic impact of structural reforms and fiscal consolidation in Italy, respectively. Gomes et al. (2013) evaluate the effects of enhancing competition in the German labor market and service sector. Different from these papers, we analyze the interaction between structural reforms in the service sector and the ZLB. From this perspective, our paper is related to Fernández-Villaverde et al. (2012) and Eggertsson et al. (2014), that assess the short-run impact of structural reforms when the monetary policy is constrained by the ZLB. Different from

them, we use a large scale model, featuring capital accumulation, and formalize the interaction of the EA with the RW. As such, we fully characterize the role of trade and international relative price dynamics. Gomes (2014) evaluates the impact of several (labor market and service sector) reforms on the ZLB. Different from this contribution, we focus on the role of service sector reforms. Crucially, given that the EA recession is associated with a financial crisis, we consider the case of implementing reforms when the aggregate and sector-specific capital are kept constant at their initial steady-state levels and, hence, investment does not react because, for example, of the presence of liquidity or financial constraints (not explicitly formalized in the model) on firms' decisions.

The paper is organized as follows. Section 2 reports the main theoretical features of the model setup and the calibration. In particular, it shows equations of the imperfect competition regime in the service sector. Section 3 reports the main results of implementing the reforms. Section 4 contains the sensitivity analysis. Section 5 concludes. Finally, the Appendix reports other equations of the model.

2 The model

The model represents a world economy composed by three regions: the Home region, REA and RW. In each region there is a continuum of symmetric households and symmetric firms. Home households are indexed by $j \in [0; s]$, households in the REA by $j^* \in (s; S]$, households in the RW by $j^{**} \in (S; 1]$.[5]

Home region and REA share the currency and the monetary authority, that sets the nominal interest rate according to EA-wide variables. The presence of the RW outside the EA allows to assess the role of the nominal exchange rate and extra-EA trade in transmitting the shocks. In each region there are households and firms. Households consume a final good, which is a composite of intermediate nontradable and tradable goods. The latter are domestically produced or imported. Households trade a one-period nominal bond, denominated in euro. They also own domestic firms and use another final good (different from the final consumption good) to invest in physical capital. The latter is rented to domestic firms in a perfectly competitive market. All households supply differentiated labor services to domestic firms and act as wage setters in monopolistically competitive labor markets by charging a markup over their marginal rate of substitution between consumption and leisure.

On the production side, there are perfectly competitive firms that produce two final goods (consumption and investment goods) and monopolistic firms that produce intermediate goods. The final goods are sold domestically and are produced combining all available intermediate goods using a constant-elasticity-of-substitution (CES) production function. The two resulting

[5]The parameter s is the size of the Home population, which is also equal to the number of firms in each Home sector (final nontradable, intermediate tradable and intermediate nontradable). Similar assumptions holds for the REA and the RW.

bundles can have different composition. Intermediate tradable and nontradable goods are produced combining domestic capital and labor, that are assumed to be mobile across sectors. Intermediate tradable goods can be sold domestically and abroad. Because intermediate goods are differentiated, firms have market power and restrict output to create excess profits. We also assume that markets for tradable goods are segmented, so that firms can set three different prices, one for each market. Similarly to other DSGE models of the EA (see, among the others, Christoffel et al. 2008 and Gomes et al. 2012), we include adjustment costs on real and nominal variables, ensuring that, in response to a shock, consumption, production and prices react in a gradual way. On the real side, habit preferences and quadratic costs prolong the adjustment of households consumption and investment, respectively. On the nominal side, quadratic costs make wages and prices sticky.[6]

In the following section we describe the monetary policy setup and, for the case of the Home region, the imperfect competition regime in the service sector and the household's problem. Similar equations, not reported to save on space, hold for other regions.[7]

2.1 Monetary authority

When it is not stuck at the ZLB, the monetary policy rate R_t is controlled by the monetary authority according to the Taylor rule. As such, the following equation holds:

$$\left(\frac{R_t}{\bar{R}}\right) = \max\left(0, \left(\frac{R_{t-1}}{\bar{R}}\right)^{\rho_R} (\Pi_{EA,t})^{(1-\rho_R)\rho_\pi} \left(\frac{GDP_{EA,t}}{GDP_{EA,t-1}}\right)^{(1-\rho_R)\rho_{GDP}}\right) \tag{1}$$

The parameter ρ_R $(0 < \rho_R < 1)$ captures inertia in interest rate setting, while the term $\bar{R}$ represents the steady state gross nominal policy rate. The parameters ρ_π and ρ_{GDP} are the weights of EA CPI inflation rate ($\Pi_{EA,t}$) and GDP ($GDP_{EA,t}$), respectively. The CPI inflation rate is a geometric average of CPI inflation rates in the Home region and the REA (Π_t and Π_t^*, respectively) with weights equal to the correspondent country size (as a share of the EA):

$$\Pi_{EA,t} \equiv (\Pi_t)^{\frac{s}{s+S}} (\Pi_t^*)^{\frac{S}{s+S}} \tag{2}$$

The EA GDP, $GDP_{EA,t}$, is the sum of the Home and REA GDPs (GDP_t and GDP_t^*, respectively):

$$GDP_{EA,t} \equiv GDP_t + rer_t * GDP_t^* \tag{3}$$

where rer_t is the Home-to-REA bilateral real exchange rate, defined as the ratio of REA to Home consumer prices. The EA monetary policy rate hits the ZLB because of negative aggregate demand shocks, as illustrated later. When it exits from the ZLB, it reverts to the Taylor rule (1). In this way it is possible to assess the role of monetary policy rate for the short- and medium-run

[6] See Rotemberg (1982).
[7] We report them in the Appendix.

effects of the structural reforms. An equation similar to 1 holds in the RW.

2.2 The role of markups

In the intermediate goods market, imperfect competition is introduced as follows. There is a large number of firms offering a continuum of different products that are imperfect substitutes. Each product is made by one monopolistic firm, which sets prices to maximize profits. The elasticity of substitution between products of different firms determines the market power of each firm. In the (long-run) flex-price steady state, in each sector (manufacturing and service sectors) a first order condition for price-setting holds:

$$\frac{P_Y}{P} = \frac{\theta_Y}{\theta_Y - 1}\frac{MC}{P}, \theta_Y > 1 \tag{4}$$

where P_Y/P is the relative price of the generic intermediate good Y and MC/P is the real marginal cost of producing Y. The markup is $\theta_Y/(\theta_Y - 1)$ and depends negatively on the elasticity of substitution between different products, θ_Y. The higher the degree of substitutability, the lower the implied markup and the higher the production level, for a given price. As such, the markup reflects imperfect competition. In the simulations we permanently increase the elasticity of substitution among nontradable intermediate goods (our proxy for services) to augment the degree of competition in that sector. In the short run, an equation similar to equation (4) holds. The only difference is that the (short-run) markup is affected not only by the (time-varying) elasticity of substitution, but also by quadratic costs a' la Rotemberg (1982) paid by the generic firm for adjusting the price of the produced good:

$$AC_t^P \equiv \frac{\kappa_P}{2}\left(\frac{P_{Y,t}}{P_{Y,t-1}} - 1\right)^2 \quad \kappa_P > 0 \tag{5}$$

2.3 Households

Households' preferences are additively separable in consumption and labor effort. The generic Home household j receives utility from consumption C and disutility from labor L. The expected value of the lifetime utility is:

$$E_0\left\{\sum_{t=0}^{\infty}\beta^t\left[\frac{\left(C_t(j) - hC_{t-1}\right)^{1-\sigma}}{(1-\sigma)} - \frac{L_t(j)^{1+\tau}}{1+\tau}\right]\right\} \tag{6}$$

where E_0 denotes the expectation conditional on information set at date 0, β is the discount factor ($0 < \beta < 1$), $1/\sigma$ is the elasticity of intertemporal substitution ($\sigma > 0$) and $1/\tau$ is the labor Frisch elasticity ($\tau > 0$). The parameter h ($0 < h < 1$) represents external habit formation in consumption.

The budget constraint of the household j is:

$$\begin{aligned}\frac{B_t(j)}{(1+R_t)} - B_{t-1}(j) \quad \leq \quad & \left(\Pi_t^P(j) + R_t^K K_{t-1}(j)\right) + \\ & + W_t(j) L_t(j) - P_t C_t(j) - P_t^I I_t(j) \\ & - AC_t^W(j)\end{aligned}$$

Home households hold a one-period bond, B_t, denominated in euro ($B_t > 0$ is a lending position). The short-term nominal rate R_t is paid at the beginning of period t and is known at time t.[8] We assume that the bonds are traded in the same international market. Households own all domestic firms and there is no international trade in claims on firms' profits. The variable Π_t^P includes profits accruing to the Home households. The variable I_t is the investment bundle in physical capital and P_t^I the related price index, which is different from the price index of consumption because the two bundles have different composition. Home households accumulate physical capital K_t and rent it to domestic firms at the nominal rate R_t^k. The law of motion of capital accumulation is:

$$K_t(j) = (1-\delta) K_{t-1}(j) + \left(1 - AC_t^I(j)\right) I_t(j) \tag{7}$$

where δ is the depreciation rate. Adjustment cost on investment AC_t^I is:

$$AC_t^I(j) \equiv \frac{\phi_I}{2}\left(\frac{I_t(j)}{I_{t-1}(j)} - 1\right)^2, \ \phi_I > 0 \tag{8}$$

Finally, Home households act as wage setters in a monopolistic competitive labor market. Each household j sets her nominal wage taking into account labor demand and adjustment costs AC_t^W on the nominal wage $W_t(j)$:

$$AC_t^W(j) \equiv \frac{\kappa_W}{2}\left(\frac{W_t(j)}{W_{t-1}(j)} - 1\right)^2 W_t L_t, \ \kappa_W > 0 \tag{9}$$

The costs are proportional to the per-capita wage bill of the overall economy, $W_t L_t$. Similar relations hold in the REA and in the RW.

2.4 Calibration

The model is calibrated at quarterly frequency. The Home country is calibrated to Italy. We set some parameters to make steady-state ratios consistent with 2012 national account data, which are the most recent and complete available data. For remaining parameters we resort to previous

[8] A financial friction μ_t is introduced to guarantee that net asset positions follow a stationary process and the economy converge to a steady state. Revenues from financial intermediation are rebated in a lump-sum way to REA households. See Benigno (2009).

studies and estimates available in the literature.[9]

Table 1 contains parameters that regulate preferences and technology. Parameters with "$*$" and "$**$" are related to the REA and the RW, respectively. Throughout we assume perfect symmetry between the REA and the RW, unless differently specified. We assume that discount rates and elasticities of substitution have the same value across the three regions. The discount factor β is set to 0.9927, so that the steady state real interest rate is equal to 3.0 per cent on an annual basis. The value for the intertemporal elasticity of substitution, $1/\sigma$, is 1. The Frisch labor elasticity is set to 0.5. The depreciation rate of capital δ is set to 0.025. Habit is set to 0.6.

In the production functions of tradables and nontradables, the elasticity of substitution between labor and capital is set to 0.93. To match investment-to-GDP ratios, the bias towards capital in the production function of tradables is set to 0.56 in the Home country and to 0.46 in the REA and the RW. The corresponding value in the production function of nontradables is set to 0.53 in Home and to 0.43 in the REA and RW. In the final consumption and investment goods the elasticity of substitution between domestic and imported tradable is set to 1.5, while the elasticity of substitution between tradables and non tradables to 0.5, as empirical evidence suggests that it is harder to substitute tradables for nontradables than to substitute across tradables. The biases towards the domestically produced good and towards the composite tradable good are chosen to match the Home and REA import-to-GDP ratios. In the consumption bundle the bias towards the domestic tradeable is 0.68 in the Home country, 0.59 in the REA and 0.90 in the RW. The bias towards the composite tradeable is set to 0.68 in the Home country, to 0.5 in the REA and the RW. For the investment basket, the bias towards the domestic tradeable is 0.50, 0.49 and 0.90. The bias towards the composite tradable is 0.78 in the Home country, 0.70 in the REA and in the RW.

Table 2 reports gross markup values, that represent updated estimates of those reported in Forni et al. (2010a). In the Home tradable and nontradable sectors and in the Home labor market the markup is set to 1.08, 1.29 and 1.60, respectively (the corresponding elasticities of substitution across varieties are set to 13.32, 4.44 and 2.65). In the REA tradable and nontradable sectors and in the REA labor market the gross markups are respectively set to 1.11, 1.24 and 1.33 (the corresponding elasticities are set to 10.15, 5.19 and 4.00). Similar values are chosen for the corresponding parameters in the RW.

Table 3 contains parameters that regulate the dynamics. The parameters are calibrated to generate dynamic adjustments for the EA similar to those obtained with the New Area Wide Model (NAWM, see Christoffel et al. 2008) and Euro Area and Global Economy Model (EAGLE, see Gomes et al. 2010). Adjustment costs on investment change are set to 6. Nominal wage quadratic adjustment costs are set to 200. In the tradable sector, we set the nominal adjustment cost parameter to 300 for Home tradable goods sold domestically and in the REA; for Home goods sold in the RW, the corresponding parameter is set to 50. The same parameterization is adopted for the REA, while for the RW we set the adjustment cost on goods exported to Home

[9] Among others, see Forni et al. (2010a, 2010b).

region and the REA to 50. Nominal price adjustment costs are set to 500 in the nontradable sector. The two parameters regulating the adjustment cost paid by the private agents on their net financial position are set to 0.00055 so that they do not greatly affect the model dynamics.

The central bank of the EA (see Table 4) targets the contemporaneous EA wide consumer price inflation (the corresponding parameter is set to 1.7) and the output growth (the parameter is set to 0.1). Interest rate is set in an inertial way and hence its previous-period value enters the rule with a weight equal to 0.87. Same values hold for the corresponding parameters of the Taylor rule in the RW.

Table 5 reports the actual great ratios which are matched in the model steady state under our baseline calibration. We assume a zero steady state net foreign asset position of each region. The size of Home and REA GDPs, as a share of world GDP, are set to 3 percent and to 17 percent, respectively.

3 Results

In this section we initially describe the simulated scenarios. Subsequently, the long-run (steady-state) results are briefly reported. Finally, we report the short-run effects of the competition reforms when the ZLB holds.

3.1 Simulated scenarios

We assume an initial negative persistent (demand) shock to worldwide private consumption and investment, lasting for three years. The EA monetary policy rate immediately hits the ZLB and stays at that level for 7 quarters. Thereafter, it gradually increases and reduces the negative difference with respect to its baseline level, as EA inflation and GDP growth return to their corresponding baseline values (see the Taylor rule, equation (1)). The Home and REA GDPs drop by 8 percent after three years. They return to their baseline level in more than 10 years. See dashed red lines in Figure 1 and Figure 3, respectively.

On top of this recessionary scenario we simulate competition-friendly reforms. We first assume that they are implemented only in the Home country. Then, we posit a simultaneous implementation in the EA. In the case of Home country, the service sector (gross) markup is gradually reduced by 10 percentage points, from 1.29 to 1.19 percent over a 5 year-period. Similarly, markup in the REA service sector is reduced by 10 percentage points, from 1.24 to 1.14. Given the assumption of perfect foresight, all reforms are fully credible, there is no uncertainty, households and firms anticipate the transition paths and the final equilibria.

3.2 Long-run effects of the reforms

Steady-state effects of the service sector reforms, implemented in isolation in the Home country and simultaneously in the Home country and the REA, are reported in Table 6.

Column (a) reports results when the markup is reduced by 10 p.p. in Home service sector. Firms increase production of services and reduce their prices. This favors the increase in demand of capital and labor for production purposes. The reduction in the price of services is an incentive for households to increase consumption, given its high services' content. The increases in GDP, consumption and investment are respectively equal to 3.2, 1.6 and 5.1 percent of their corresponding initial levels. Employment also increases, by 1.5 percent. Home exports and imports increase, by 1.4 and 0.5 percent, respectively.

The terms of trade deterioration is lower than the real exchange rate depreciation. The reason is that the increase in the relative price of Home tradables partially counterbalances the decrease in the price of services. The increase in the price of Home tradables (expressed in Home consumption units) is due to the higher demand of Home inputs (labor and capital). The latter drives up the marginal cost also in the manufacturing sector. Finally, spillovers to the REA are small (the increases in GDP in the REA is muted).

Column (b) reports results when the markup is reduced by 10 p.p. in the Home and REA service sectors.

Results for Home and the REA are qualitatively similar. For the Home region results do not greatly change relatively to the case of unilateral Home implementation. The Home GDP now increase by 3.3 instead of 3.2 percent. The EA GDP increases by 2.5 percent. The Home economy benefits from a lower deterioration of the international relative prices, as now there is an excess supply of goods also in the REA. This improves the purchasing power of Home households and firms, that increase consumption and investment and, hence, imports. Home exports increase relatively more, favored by the increase in REA aggregate demand.

Overall, results suggest there are long-run macroeconomic benefits from implementing reforms at both country-specific and EA-wide levels.

3.3 Short and medium-run effects and the ZLB

The previous section has shown the expansionary long-run effects of reforms. In this section we assess the corresponding short-run effects under the assumption that the ZLB holds. We initially assume unilateral implementation of reforms in the Home country and thereafter a simultaneous implementation in the EA. The goal is to evaluate if the reforms allow the EA economy to get out of the ZLB and improve the short-term outlook.

3.3.1 Unilateral Home implementation

Figure 1 shows the macroeconomic effects of the competition reform in the Home service sector (black solid line). The short-run GDP decrease induced by the negative world-wide aggregate demand shock is slightly attenuated. As reforms are implemented in a gradual way, they do not have substantial effects in the short run. There is a small additional decrease in consumption compared to the ZLB scenario. It is associated with Home households anticipating that services will be cheaper in future than in current periods, when their supply will be large. Given its high service content, households postpone consumption to future periods. Short-run investment is slightly larger in the case of reforms than in the ZLB scenario. The additional investment demand is needed to gradually build up the stock of capital, to increase production in correspondence of higher competition. Export decrease less, because the Home real exchange rate depreciation favors the absorption of the excess supply of Home goods and services.[10]

Differences continue to be relatively mild in the medium run (three years from the beginning of the reform implementation), as GDP increases slightly more when the reforms are enacted compared to the ZLB scenario. The additional increase is driven by investment and exports.

Overall, the Home unilateral implementation of reforms improves only slightly the domestic medium-run macroeconomic outlook when both worldwide recession and the ZLB hold. Home spillovers to the REA are small and there are no major changes in REA economic performance. As such, the duration of the ZLB does not change, because it depends on the economic performance of the EA.

3.3.2 Simultaneous implementation in the EA

Figures 2-3 show results when competition is simultaneously increased in the Home region and the REA. As for the Home region, the markup in the REA service sector is gradually decreased by 10 percentage points over a five-year period. Economic activity increases in the EA. Crucially, both the Home and REA economies get out of the ZLB earlier than in the benchmark scenario. The reason is that EA inflation decreases to a lower extent than in the ZLB scenario. Firms anticipate a permanent increase in aggregate demand for investment, because of the reforms. Demand for domestic and imported manufacturing goods increases because of the complementarity between manufacturing goods and (nontradable) services. The higher demand implies higher manufacturing goods inflation. For domestic manufacturing goods, inflation increases also because of higher marginal costs, as the reform in the service sector drives up the demand for domestic productive factors (labor and capital) and, hence, their prices. The excess supply of services favors the EA nominal and real exchange rate depreciation, that induces an increase in foreign demand for EA tradables. Moreover, the exchange rate depreciation is gradually passed-through into the prices of imported goods. The implied increase in manufacturing goods' inflation more than counterbalances the decrease in services inflation. Overall inflation

[10] Spillover effects to the REA are small. They are not reported to save on space.

decreases to a lower extent than in the ZLB scenario. The monetary policy rate gets out of the ZLB sooner and gradually moves to its baseline level, following the gradual return of inflation and the economic activity towards their corresponding benchmark values.

EA consumption, labor and, more crucially, investment, increase relative to the ZLB scenario, because the kick-in of the reform favors a quicker increase in aggregate demand and economic activity. The difference between the corresponding variables in the "ZLB" and "reforms" scenarios increases as time goes by.

In comparison with the case of unilateral implementation (see Figure 1), the Home economy faces an additional expansionary effect. Home exports increase relatively more, because of the increase in demand of investment in the REA.

Overall, the short-run expansionary effects of reforms simultaneously implemented in the EA imply that the EA economy is stuck at the ZLB for a lower amount of time. Moreover, the short-run expansionary effects on the Home economy of domestic reforms are magnified if similar reforms are simultaneously implemented in the REA.

3.4 Role of timing of reforms and investment in physical capital

To further assess the role of the supply and demand sides of the economy in driving the economy out of the ZLB, we initially evaluate the role of the speed in implementing the reforms, assuming that the reform is fully implemented in quarter one and not in a gradual fashion. Thereafter, we assume that investment and, hence, physical capital do not change but remain constant at their initial steady-state levels. In what follows, we focus on the case of service sector reforms simultaneously implemented in the Home region and the REA, as it is the most interesting one.

3.4.1 Sudden implementation of reforms

Figure 4 shows results for the following scenarios. First, for the ease of comparison, we newly report the results of the scenario where no reforms are implemented and the EA economy is negatively affected by the negative worldwide aggregate demand shock ("ZLB") and the scenario where EA-wide reforms are implemented on top of the negative demand shock ("benchmark"). In addition, we include the, rather extreme, scenario where, on top of the negative aggregate demand shock, the reforms are fully implemented in quarter one ("sudden"). This corresponds to an immediate markup decrease to its new long-run level in both Home and the REA. In the benchmark case the reforms are gradually implemented, over five years. To save on space, we report results for REA GDP and inflation, as results for corresponding Home variables are similar. The GDP response is rather similar across the two scenarios. The short-run improvement in economic activity is larger under the sudden implementation (green line with circles), as there is a larger incentive for firms to immediately raise capital and, hence, demand for investment. More importantly, GDP increases even if the ZLB lasts for a longer amount of time than in the

benchmark case of gradual implementation, since inflation is lower. The reason is that the supply side of the economy increases more than the demand side does in the initial periods, inducing a fall in prices. The demand side of the economy still increases, because of the increase in the expected return of physical capital, that drives up short-run investment, and because of the positive wealth effect, that drives up short-run consumption. Both effects dominate the negative effect associated with the increase in the real interest rate.

3.4.2 The role of investment in physical capital

The purpose of the simulation is to illustrate the relevance of investment response for the impact of the reforms on the ZLB constraint. The following assumptions are made. First, in the EA the demand for investment, and hence physical capital, at both aggregate and sectoral levels, are held constant at the initial steady state. Such assumption approximates a situation in which firms are financially constrained and face limits in credit supply. As such, the higher demand for investment induced by the reforms in the service sector cannot be adequately financed and, therefore, new capital cannot be accumulated to meet the expected higher levels of production. Second, it is assumed that the negative demand shocks are such that the EA economy is stuck at the ZLB for 12 quarters. Third, EA reforms are immediately fully implemented, so that EA markups immediately (in the first quarter) decrease by 10 percentage points. The latter two assumptions allow to magnify the response of the supply-side of the economy to the reform and, hence, help clarify the underlying transmission mechanism. Figure 5 reports the results (1) under ZLB only, (2) when the reforms are suddenly implemented or, for comparison, (3) reforms are gradually (over five years) implemented on top of the shocks driving the economy to the ZLB.[11] The length of the ZLB does not decrease when reforms are suddenly implemented and there is no role for physical capital. Now investment does not increase, so inflation decreases relatively more under the "sudden reforms" scenario, because of the initial excess supply. The real interest rate increases more, amplifying the supply-side effect of the reform and, hence, pushing down consumption and real GDP in the initial quarters. Interestingly, a gradual implementation of the reforms does not have such a deflationary effect, as the initial increase in the supply-side of the economy is lower and, hence, the negative impact on inflation is more muted.[12]

Overall, the figure suggests that investment response can be crucial for reforms being able to get the economy out of the ZLB, in particular if reforms have a relatively large and quick supply-side effect. Investment is the component of the aggregate demand that positively reacts to the reforms. More crucially, investment magnifies the wealth effect of the reforms, associated with the increase in permanent income. This effect contributes to counterbalance the supply-side expansion of the reforms and its negative effect on short-run inflation, as also suggested by

[11] To save on space, we report results for REA GDP and inflation, as results for corresponding Home variables are similar.

[12] We have also considered the case of transitory reforms, where the markup is immediately decreased and thereafter gradually returns to its initial level. Results, available upon request, suggest that reforms can induce a fall of GDP larger than those reported in the figure.

Fernández-Villaverde (2014).[13]

4 Sensitivity analysis

We report results of the sensitivity analysis. We initially consider the case of reforms implemented in correspondence of higher adjustment costs on investment and, thereafter, in correspondence of high price stickiness for exported and imported goods. In all cases, as in previous simulations, reforms are implemented on top of the negative aggregate demand shock.

4.1 Higher adjustment costs on capital

We double the value of adjustment costs on EA investment (from 6 to 12). Figure 6 shows the results. Overall, they do not greatly change relatively to the benchmark case. Short-run GDP increases relatively to the case of the ZLB. The increase is lower than in the benchmark scenario (see Figure 3), as investment increases to a lower extent in the short run. Consistent with the lower increase in aggregate demand, inflation increases to a lower extent relatively to the ZLB case than in the benchmark case. However, the relative increase is large enough to favor the earlier exit from the ZLB.

4.2 Higher price stickiness

In this simulation prices of exported and imported tradables are as sticky as prices of tradables sold domestically (in the benchmark case the former are more flexible than the latter), in order to limit the short-run impact of international relative prices. Results are reported in Figure 7. They do not greatly change relatively to the benchmark case. Inflation increases relatively to the ZLB scenario, albeit to a lower extent than in the benchmark case. Relatively to the ZLB scenario, the GDP increases and the monetary policy rate decreases to a lower extent. As for inflation, GDP and interest rate paths are similar to those in the benchmark case.

5 Conclusions

We have evaluated the short-run macroeconomic effects of implementing structural (supply-side) reforms in the EA when the ZLB holds. Our results suggest that EA reforms tend to reduce the length of the ZLB if they induce a sufficiently large increase in aggregate demand relative to aggregate supply. The increase in GDP is associated with the increase in demand for investment and in net exports. Higher investment is favored by the expected future permanent increase in production. Higher net exports are due to the real exchange rate depreciation, as the overall

[13]The EA economy is stimulated when the investment is free to react to the reforms. To save on space we do not report the results, as they are in line with those reported in the previous section.

supply of goods produced in the EA increases. If investment does not react, possibly reflecting the existence of binding financial constraints, then the deflationary impact of the reforms is magnified and the length of the ZLB is not reduced. Finally, reforms implemented by one country member apart have short-run expansionary effects, but they do not affect the length of the ZLB.

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Table 1. Parametrization of Home, the rest of the euro area and the rest of the world

Parameter	Home	REA	RW
Discount rate β	$1.03^{-0.25}$	$1.03^{-0.25}$	$1.03^{-0.25}$
Intertemporal elasticity of substitution $1/\sigma$	1.0	1.0	1.0
Inverse of Frisch Elasticity of Labor Supply τ	2.0	2.0	2.0
Habit h	0.6	0.6	0.6
Depreciation rate of (private and public) capital δ	0.025	0.025	0.025
Tradable Intermediate Goods			
Substitution between factors of production $\xi_T, \xi_T^*, \xi_T^{**}$	0.93	0.93	0.93
Bias towards capital $\alpha_T, \alpha_T^*, \alpha_T^{**}$	0.56	0.46	0.46
Non tradable Intermediate Goods			
Substitution between factors of production $\xi_N, \xi_N^*, \xi_N^{**}$	0.93	0.93	0.93
Bias towards capital $\alpha_N, \alpha_N^*, \alpha_N^{**}$	0.53	0.43	0.43
Final consumption goods			
Substitution between domestic and imported goods $\phi_A, \phi_A^*, \phi_A^{**}$	1.50	1.50	1.50
Bias towards domestic tradable goods a_H, a_F^*, a_G^*	0.68	0.59	0.90
Substitution between domestic tradables and non tradables $\rho_A, \rho_A^*, \rho_A^{**}$	0.50	0.50	0.50
Bias towards tradable goods a_T, a_T^*, a_T^{**}	0.68	0.50	0.50
Final investment goods			
Substitution between domestic and imported goods $\phi_E, \phi_E^*, \phi_E^{**}$	1.50	1.50	1.50
Bias towards domestic tradable goods υ_H, υ_F^*	0.50	0.49	0.90
Substitution between domestic tradables and non tradables ρ_E, ρ_E^*	0.50	0.50	0.50
Bias towards tradable goods υ_T, υ_T^*	0.78	0.70	0.70

Note: REA=Rest of the euro area; RW= Rest of the world.

Table 2. Gross Markups

Markups and Elasticities of Substitution			
	Tradables	nontradables	Wages
Home	1.08 ($\theta_T = 13.32$)	1.29 ($\theta_N = 4.44$)	1.60 ($\psi = 2.65$)
REA	1.11 ($\theta_T^* = 10.15$)	1.24 ($\theta_N^* = 5.19$)	1.33 ($\psi^* = 4$)
RW	1.11 ($\theta_T^{**} = 10.15$)	1.24 ($\theta_N^{**} = 5.19$)	1.33 ($\psi^{**} = 4$)

Note: REA=rest of the euro area; RW= rest of the world.

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Table 3. Real and Nominal Adjustment Costs

Parameter ("*" refers to rest of the Euro area)	Home	REA	RW
Real Adjustment Costs			
Investment ϕ_I, ϕ_I^*, ϕ_I^{**}	6.00	6.00	6.00
Households' financial net position $\phi_{b1,}\phi_{b2}$	0.00055, 0.00055	-	0.00055, 0.00055
Nominal Adjustment Costs			
Wages κ_W, κ_W^*, κ_W^{**}	200	200	200
Home produced tradables κ_H, k_H^* k_H^{**}	300	300	50
REA produced tradables κ_H, k_H^* k_H^{**}	300	300	50
RW produced tradables κ_H, k_H^* k_H^{**}	50	50	300
nontradables κ_N, κ_N^*, κ_N^{**}	500	500	500

Note: REA=rest of the euro area; RW= rest of the world.

Table 4. Monetary Policy Rules

Parameter	Home	REA	EA	RW
	-	-		
Lagged interest rate at t-1 ρ_R, ρ_R^{**}	-	-	0.87	0.87
Inflation ρ_Π, ρ_Π^{**}	-	-	1.70	1.70
GDP growth $\rho_{GDP}, \rho_{GDP}^{**}$	-	-	0.10	0.10

Note: REA=rest of the euro area; EA= euro area; RW= rest of the world.

Table 5. Main macroeconomic variables (ratio to GDP) and tax rates

	Home	REA	RW
Macroeconomic variables			
Private consumption	61.0	57.1	64.0
Private Investment	18.0	16.0	20.0
Public purchases	20.0	20.0	20.0
Imports	29.0	24.3	4.25
Net Foreign Asset Position	0.0	0.0	0.0
GDP (share of world GDP)	0.03	0.17	0.80

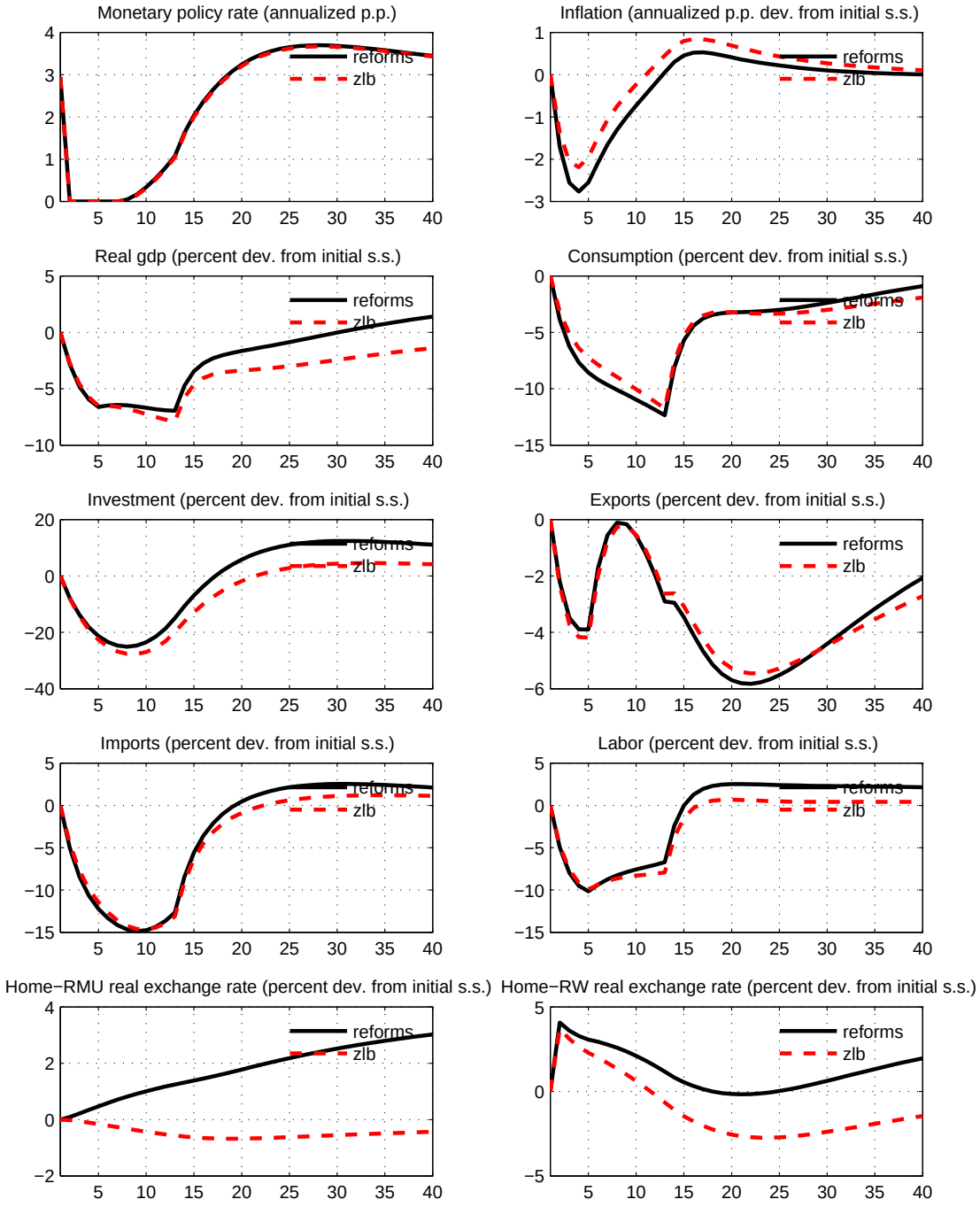
Note: REA= Rest of the euro area; RW= Rest of the world. Sources: European Commission (2012).

Table 6. Long-run effects of fiscal and competition reforms. Main macroeconomic variables

	(a) services	(b) EA services reform
Home		
GDP	3.21	3.29
Consumption	1.62	1.83
Investment	5.06	5.28
Exports	1.38	1.53
Imports	0.45	0.89
Labor	1.55	1.53
Real exch. rate (vis-à-vis REA)	3.99	-0.76
Real exch. rate (vis-à-vis RW)	3.98	4.10
Terms of trade (vis-à-vis REA)	0.93	0.24
Terms of trade (vis-à-vis RW)	0.91	0.99
REA		
GDP	0.03	2.48

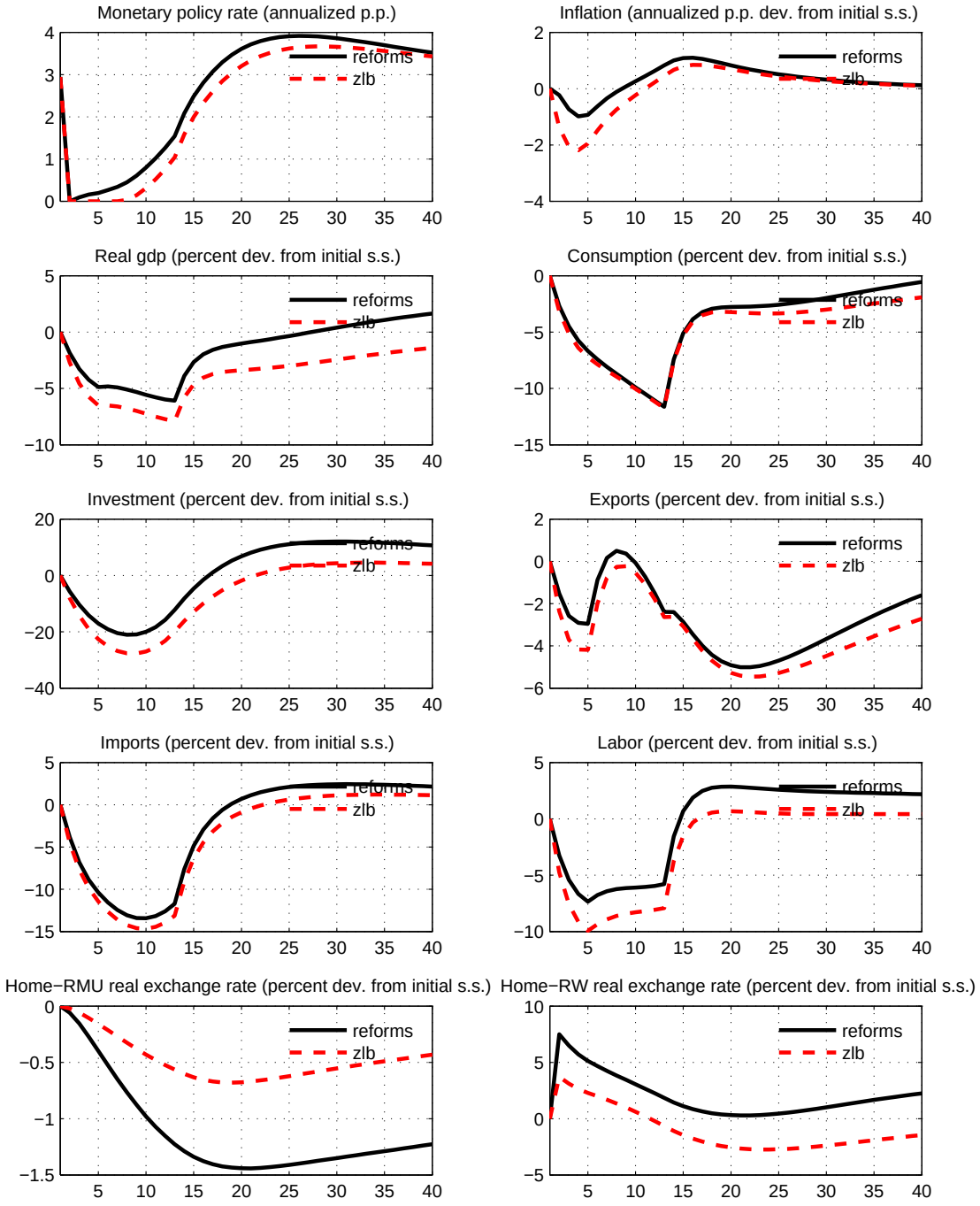
Note: % deviations from initial steady state. For real exchange rate, +=depreciation, for terms of trade +=deterioration. REA=rest of the euro area.

Figure 1. Increasing competition in the Home service sector



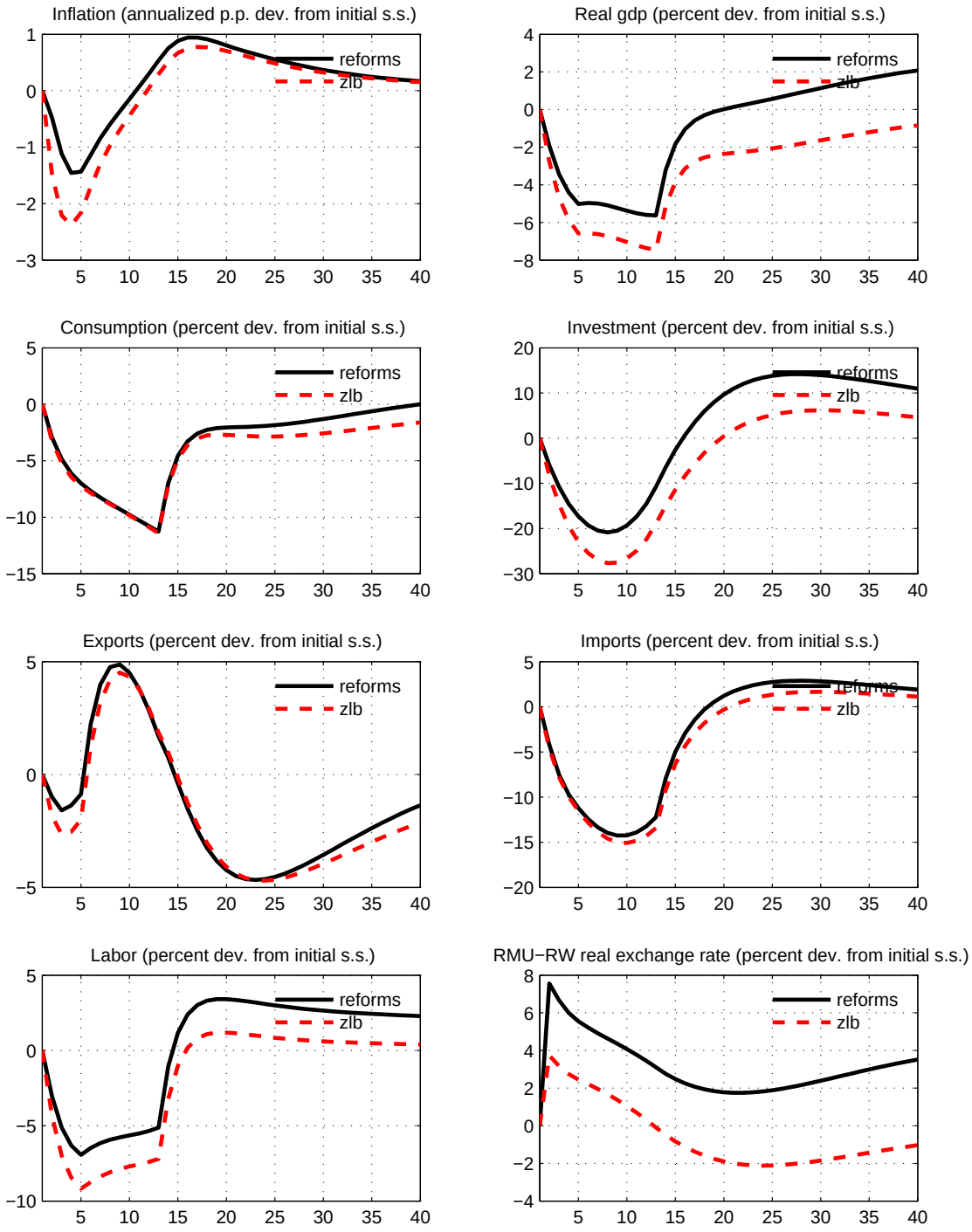
Note. Horizontal axis: quarters

Figure 2. Increasing competition in the EA service sector. Home variables



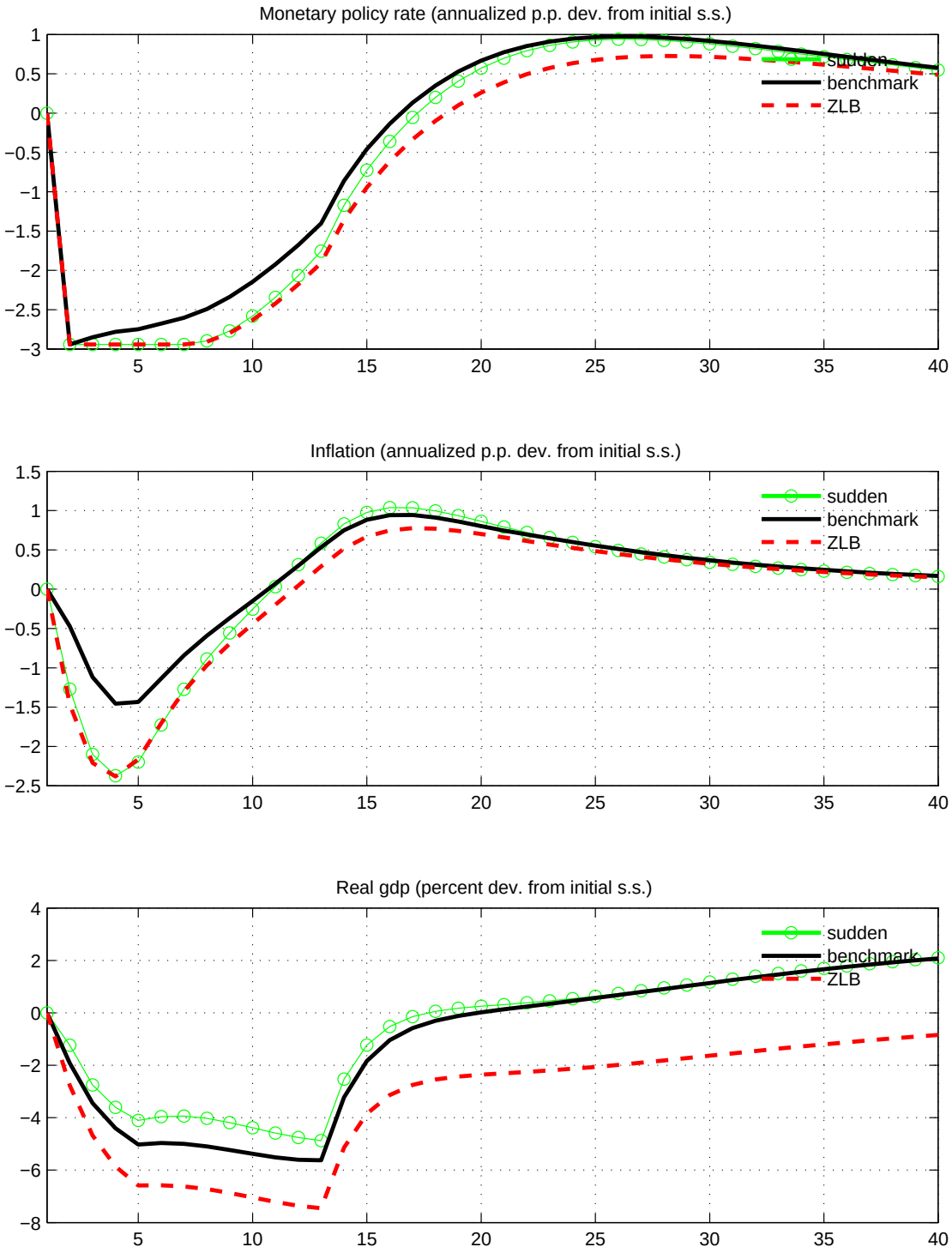
Note. Horizontal axis: quarters

Figure 3. Increasing competition in the EA service sector. REA variables



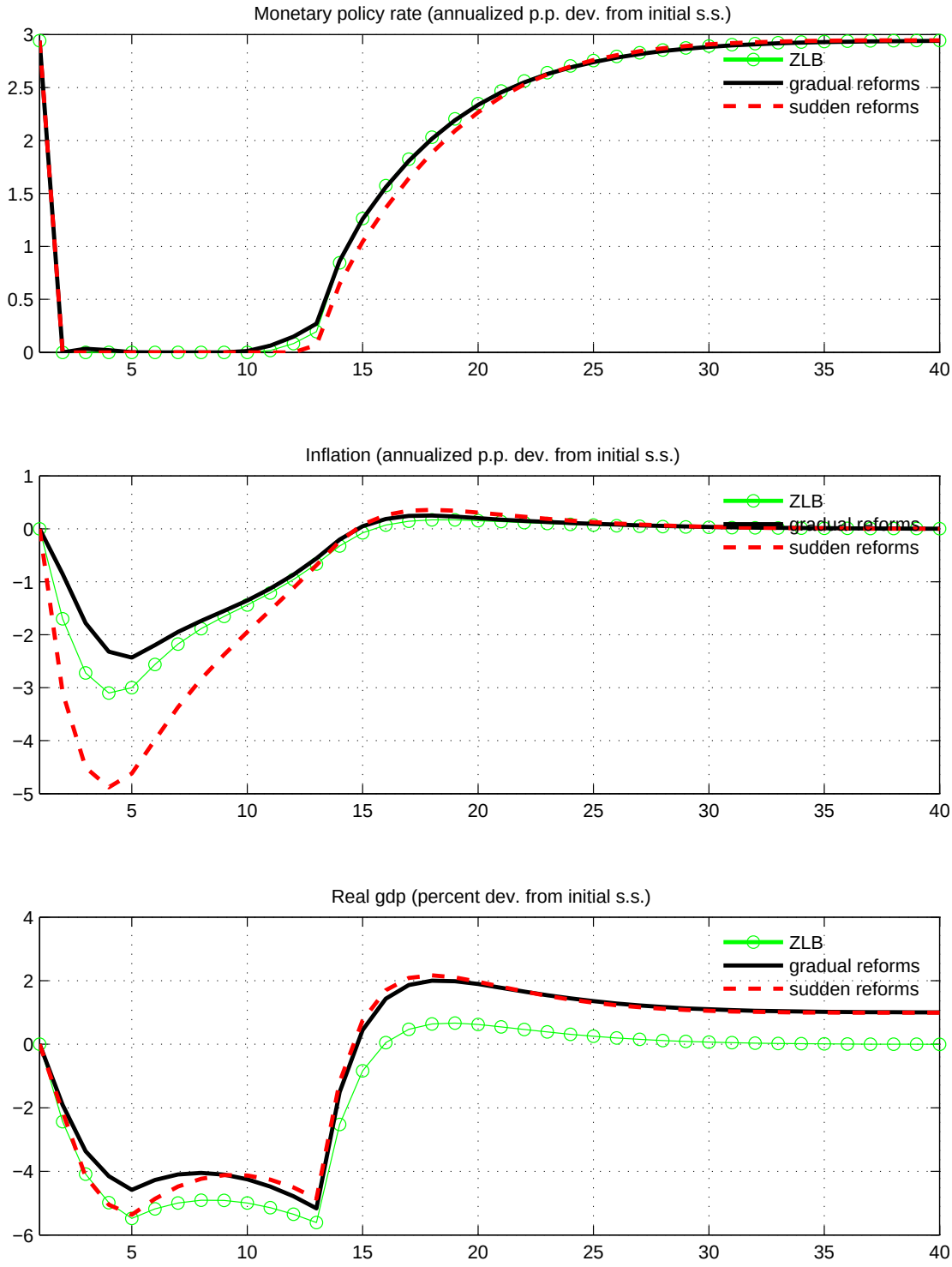
Note. Horizontal axis: quarters

Figure 4. Sudden increase in competition in the EA service sector. REA variables



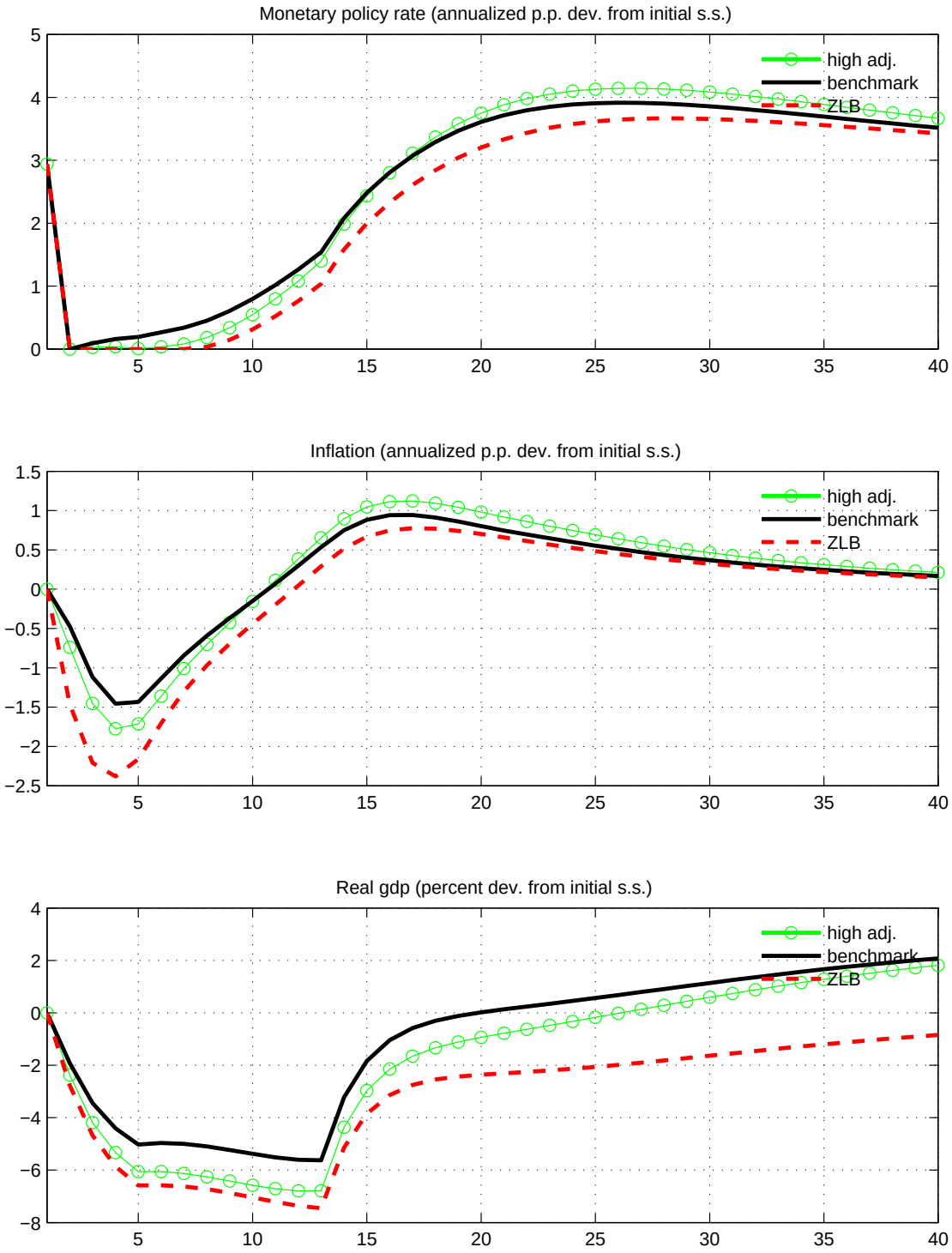
Note. Horizontal axis: quarters

Figure 5. Sudden increase in competition in the EA service sector and no change in EA investment in physical capital. REA variables



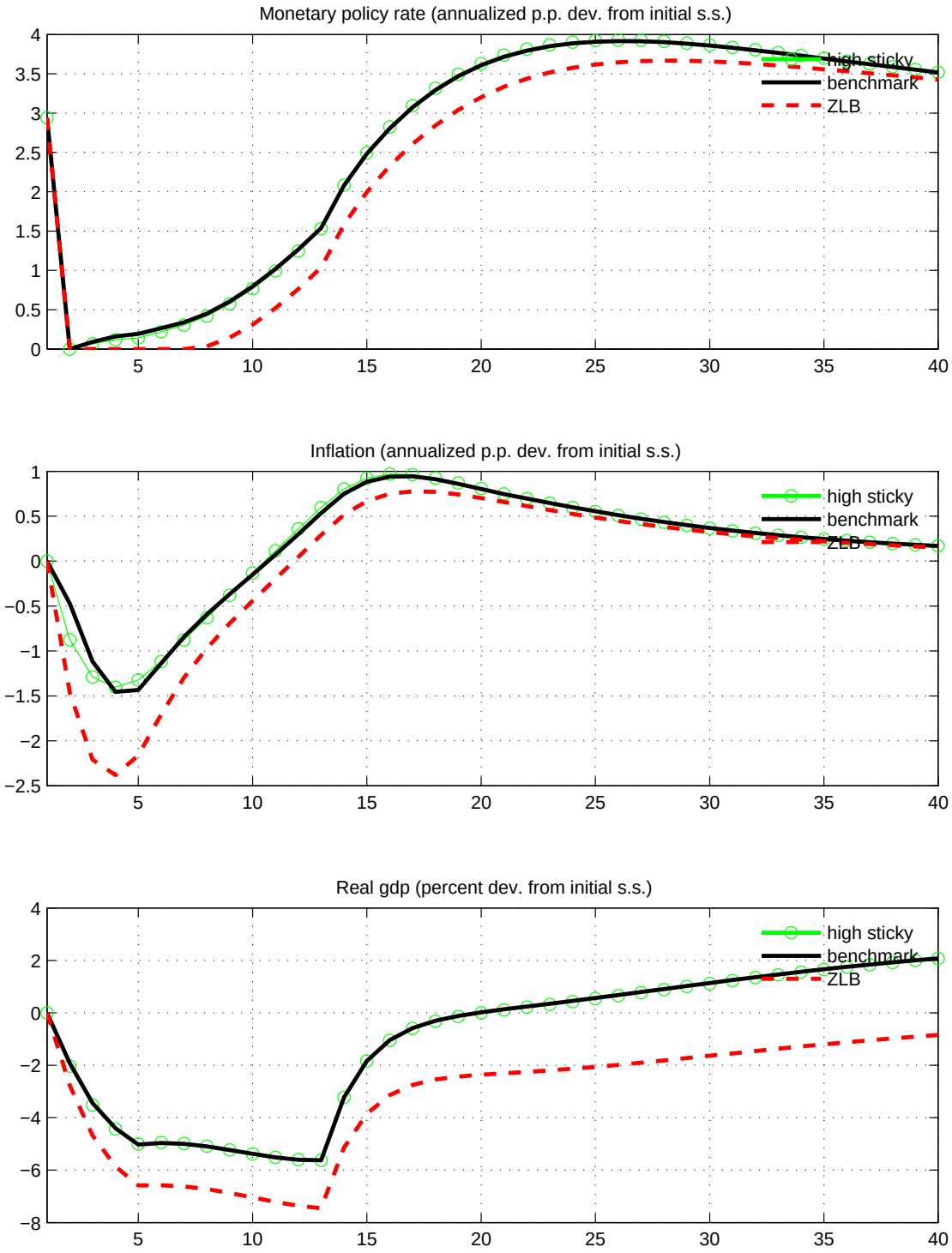
Note. Horizontal axis: quarters

Figure 6. Sensitivity. Adjustment cost on investment. REA variables



Note. Horizontal axis: quarters

Figure 7. Sensitivity. High price stickiness. REA variables



Note. Horizontal axis: quarters

Appendix

In this Appendix we report a detailed description of the model, excluding the fiscal and monetary policy part and the description of the households optimization problem that are reported in the main text.[14]

There are three countries, Home, REA and RW. They have different sizes. The Home region and the REA share the currency and the monetary authority. In each region there are households and firms. Each household consumes a final composite good made of nontradable, domestic tradable and imported intermediate goods. Households have access to financial markets and smooth consumption by trading a risk-free one-period nominal bond, denominated in euro. They also own domestic firms and capital stock, which is rent to domestic firms in a perfectly competitive market. Households supply differentiated labor services to domestic firms and act as wage setters in monopolistically competitive markets by charging a markup over their marginal rate of substitution.

On the production side, there are perfectly competitive firms that produce the final goods and monopolistic firms that produce the intermediate goods. Two final goods (private consumption and private investment) are produced combining all available intermediate goods according to constant-elasticity-of-substitution bundle. The public consumption good is a bundle of intermediate nontradable goods.

Tradable and nontradable intermediate goods are produced combining capital and labor in the same way. Tradable intermediate goods can be sold domestically or abroad. Because intermediate goods are differentiated, firms have market power and restrict output to create excess profits. We assume that goods markets are internationally segmented and the law of one price for tradables does not hold. Hence, each firm producing a tradable good sets three prices, one for the domestic market and the other two for the export market (one for each region). Since the firm faces the same marginal costs regardless of the scale of production in each market, the different price-setting problems are independent of each other.

To capture the empirical persistence of the aggregate data and generate realistic dynamics, we include adjustment costs on real and nominal variables, ensuring that, in response to a shock, consumption and production react in a gradual way. On the real side, quadratic costs and habit prolong the adjustment of the investment and consumption. On the nominal side, quadratic costs make wage and prices sticky.

In what follows we illustrate the Home economy. The structure of each of the other two regions (REA and the RW) is similar and to save on space we do not report it.

[14] For a detailed description of the main features of the model see also Bayoumi (2004) and Pesenti (2008).

5.1 Final consumption and investment goods

There is a continuum of symmetric Home firms producing final nontradable consumption under perfect competition. Each firm producing the consumption good is indexed by $x \in (0, s]$, where the parameter $0 < s < 1$ measures the size of Home. Firms in the REA and in the RW are indexed by $x^* \in (s, S]$ and $x^{**} \in (S, 1]$, respectively (the size of the world economy is normalized to 1). The CES production technology used by the generic firm x is:

$$A_t(x) \equiv \left(\begin{array}{c} a_T^{\frac{1}{\phi_A}} \left(a_H^{\frac{1}{\rho_A}} Q_{HA,t}(x)^{\frac{\rho_A - 1}{\rho_A}} + a_G^{\frac{1}{\rho_A}} Q_{GA,t}(x)^{\frac{\rho_A - 1}{\rho_A}} (1 - a_H - a_G)^{\frac{1}{\rho_A}} Q_{FA,t}(x)^{\frac{\rho_A - 1}{\rho_A}} \right)^{\frac{\rho_A}{\rho_A - 1} \frac{\phi_A - 1}{\phi_A}} \\ + (1 - a_T)^{\frac{1}{\phi_A}} Q_{NA,t}(x)^{\frac{\phi_A - 1}{\phi_A}} \end{array} \right)^{\frac{\phi_A}{\phi_A - 1}}$$

where Q_{HA}, Q_{GA}, Q_{FA} and Q_{NA} are bundles of respectively intermediate tradables produced in Home, intermediate tradables produced in the REA, intermediate tradables produced in the RW and intermediate nontradables produced in the Home country. The parameter $\rho_A > 0$ is the elasticity of substitution between tradables and $\phi_A > 0$ is the elasticity of substitution between tradable and nontradable goods. The parameter a_H $(0 < a_H < 1)$ is the weight of the Home tradable, the parameter a_G $(0 < a_G < 1)$ the weight of tradables imported from the REA, a_T $(0 < a_T < 1)$ the weight of tradable goods.

The production of investment good is similar. There are symmetric Home firms under perfect competition indexed by $y \in (0, s]$. Firms in the REA and in the RW are indexed by $y^* \in (s, S]$ and $y^{**} \in (S, 1]$. Output of the generic Home firm y is:

$$E_t(y) \equiv \left(\begin{array}{c} v_T^{\frac{1}{\phi_E}} \left(v_H^{\frac{1}{\rho_E}} Q_{HE,t}(y)^{\frac{\rho_E - 1}{\rho_E}} + v_G^{\frac{1}{\rho_E}} Q_{GE,t}(y)^{\frac{\rho_E - 1}{\rho_E}} + (1 - v_H - v_G)^{\frac{1}{\rho_E}} Q_{FE,t}(y)^{\frac{\rho_E - 1}{\rho_E}} \right)^{\frac{\rho_E}{\rho_E - 1} \frac{\phi_E - 1}{\phi_E}} \\ + (1 - v_T)^{\frac{1}{\phi_E}} Q_{NE,t}(y)^{\frac{\phi_E - 1}{\phi_E}} \end{array} \right)^{\frac{\phi_E}{\phi_E - 1}}$$

Finally, we assume that public expenditure C^g is composed by intermediate nontradable goods only.

5.2 Intermediate goods

5.2.1 Demand

Bundles used to produce the final consumption goods are CES indexes of differentiated intermediate goods, each produced by a single firm under conditions of monopolistic competition:

$$Q_{HA}(x) \equiv \left[\left(\frac{1}{s}\right)^{\theta_T}\int_0^s Q(h,x)^{\frac{\theta_T-1}{\theta_T}}\,dh\right]^{\frac{\theta_T}{\theta_T-1}} \tag{10}$$

$$Q_{GA}(x) \equiv \left[\left(\frac{1}{S-s}\right)^{\theta_T}\int_s^S Q(g,x)^{\frac{\theta_T-1}{\theta_T}}\,dg\right]^{\frac{\theta_T}{\theta_T-1}} \tag{11}$$

$$Q_{FA}(x) \equiv \left[\left(\frac{1}{1-S}\right)^{\theta_T}\int_S^1 Q(f,x)^{\frac{\theta_T-1}{\theta_T}}\,df\right]^{\frac{\theta_T}{\theta_T-1}} \tag{12}$$

$$Q_{NA}(x) \equiv \left[\left(\frac{1}{s}\right)^{\theta_N}\int_0^s Q(n,x)^{\frac{\theta_N-1}{\theta_N}}\,dn\right]^{\frac{\theta_N}{\theta_T-1}} \tag{13}$$

where firms in the Home intermediate tradable and nontradable sectors are respectively indexed by $h \in (0,s)$ and $n \in (0,s)$, firms in the REA by $g \in (s,S]$ and firms in the RW by $f \in (S,1]$. Parameters θ_T, $\theta_N > 1$ are respectively the elasticity of substitution across brands in the tradable and nontradable sector. The prices of the intermediate nontradable goods are denoted $p(n)$. Each firm x takes these prices as given when minimizing production costs of the final good. The resulting demand for intermediate nontradable input n is:

$$Q_{A,t}(n,x) = \left(\frac{1}{s}\right)\left(\frac{P_t(n)}{P_{N,t}}\right)^{-\theta_N} Q_{NA,t}(x) \tag{14}$$

where $P_{N,t}$ is the cost-minimizing price of one basket of local intermediates:

$$P_{N,t} = \left[\int_0^s P_t(n)^{1-\theta_N}\,dn\right]^{\frac{1}{1-\theta_N}} \tag{15}$$

We can derive $Q_A(h,x)$, $Q_A(f,x)$, $C_A^g(h,x)$, $C_A^g(f,x)$, P_H and P_F in a similar way. Firms y producing the final investment goods have similar demand curves. Aggregating over x and y, it can be shown that total demand for intermediate nontradable good n is:

$$\begin{aligned}&\int_0^s Q_{A,t}(n,x)\,dx + \int_0^s Q_{E,t}(n,y)\,dy + \int_0^s C_t^g(n,x)\,dx\\ =\ &\left(\frac{P_t(n)}{P_{N,t}}\right)^{-\theta_N}\left(Q_{NA,t} + Q_{NE,t} + C_{N,t}^g\right)\end{aligned}$$

where C_N^g is public sector consumption. Home demands for (intermediate) domestic and imported tradable goods can be derived in a similar way.

5.2.2 Supply

The supply of each Home intermediate nontradable good n is denoted by $N^S(n)$:

$$N_t^S(n) = \left((1-\alpha_N)^{\frac{1}{\xi_N}} L_{N,t}(n)^{\frac{\xi_N - 1}{\xi_N}} + \alpha^{\frac{1}{\xi_N}} K_{N,t}(n)^{\frac{\xi_N - 1}{\xi_N}} \right)^{\frac{\xi_N}{\xi_N - 1}} \tag{16}$$

Firm n uses labor $L_{N,t}^p(n)$ and capital $K_{N,t}(n)$ with constant elasticity of input substitution $\xi_N > 0$ and capital weight $0 < \alpha_N < 1$. Firms producing intermediate goods take the prices of labor inputs and capital as given. Denoting W_t the nominal wage index and R_t^K the nominal rental price of capital, cost minimization implies:

$$L_{N,t}(n) = (1-\alpha_N) \left(\frac{W_t}{MC_{N,t}(n)} \right)^{-\xi_N} N_t^S(n) \tag{17}$$

$$K_{N,t}(n) = \alpha \left(\frac{R_t^K}{MC_{N,t}(n)} \right)^{-\xi_N} N_t^S(n)$$

where $MC_{N,t}(n)$ is the nominal marginal cost:

$$MC_{N,t}(n) = \left((1-\alpha) W_t^{1-\xi_N} + \alpha \left(R_t^K \right)^{1-\xi_N} \right)^{\frac{1}{1-\xi_N}} \tag{18}$$

The productions of each Home tradable good, $T^S(h)$, is similarly characterized.

5.2.3 Price setting in the intermediate sector

Consider now profit maximization in the Home intermediate nontradable sector. Each firm n sets the price $p_t(n)$ by maximizing the present discounted value of profits subject to the demand constraint and the quadratic adjustment costs:

$$AC_{N,t}^p(n) \equiv \frac{\kappa_N^p}{2} \left(\frac{P_t(n)}{P_{t-1}(n)} - 1 \right)^2 Q_{N,t} \quad \kappa_N^p \geq 0$$

paid in unit of sectorial product $Q_{N,t}$ and where κ_N^p measures the degree of price stickiness. The resulting first-order condition, expressed in terms of domestic consumption, is:

$$p_t(n) = \frac{\theta_N}{\theta_N - 1} mc_t(n) - \frac{A_t(n)}{\theta_N - 1} \tag{19}$$

where $mc_t(n)$ is the real marginal cost and $A(n)$ contains terms related to the presence of price adjustment costs:

$$\begin{aligned} A_t(n) &\approx \kappa_N^p \frac{P_t(n)}{P_{t-1}(n)}\left(\frac{P_t(n)}{P_{t-1}(n)}-1\right) \\ &\quad -\beta\kappa_N^p \frac{P_{t+1}(n)}{P_t(n)}\left(\frac{P_{t+1}(n)}{P_t(n)}-1\right)\frac{Q_{N,t+1}}{Q_{N,t}} \end{aligned}$$

The above equations clarify the link between imperfect competition and nominal rigidities. As emphasized by Bayoumi et al. (2004), when the elasticity of substitution θ_N is very large and hence the competition in the sector is high, prices closely follow marginal costs, even though adjustment costs are large. To the contrary, it may be optimal to maintain stable prices and accommodate changes in demand through supply adjustments when the average markup over marginal costs is relatively high. If prices were flexible, optimal pricing would collapse to the standard pricing rule of constant markup over marginal costs (expressed in units of domestic consumption):

$$p_t(n) = \frac{\theta_N}{\theta_N - 1} mc_{N,t}(n) \tag{20}$$

Firms operating in the intermediate tradable sector solve a similar problem. We assume that there is market segmentation. Hence the firm producing the brand h chooses $p_t(h)$ in the Home market,a price $p_t^*(h)$ in the REA and a price $p_t^{**}(h)$ in the RW to maximize the expected flow of profits (in terms of domestic consumption units):

$$E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left[\begin{array}{c} p_\tau(h) y_\tau(h) + p_\tau^*(h) y_\tau^*(h) + p_\tau^{**}(h) y_\tau^{**}(h) \\ -mc_{H,\tau}(h)\left(y_\tau(h) + y_\tau^*(h) + y_\tau^{**}(h)\right) \end{array} \right]$$

subject to quadratic price adjustment costs similar to those considered for nontradables and standard demand constraints. The term E_t denotes the expectation operator conditional on the information set at time t, $\Lambda_{t,\tau}$ is the appropriate discount rate and $mc_{H,t}(h)$ is the real marginal cost. The first order conditions with respect to $p_t(h)$, $p_t^*(h)$ and $p_t^{**}(h)$ are:

$$p_t(h) = \frac{\theta_T}{\theta_T - 1} mc_t(h) - \frac{A_t(h)}{\theta_T - 1} \tag{21}$$

$$p_t^*(h) = \frac{\theta_T}{\theta_T - 1} mc_t(h) - \frac{A_t^*(h)}{\theta_T - 1} \tag{22}$$

$$p_t^{**}(h) = \frac{\theta_T}{\theta_T - 1} mc_t(h) - \frac{A_t^{**}(h)}{\theta_T - 1} \tag{23}$$

where θ_T is the elasticity of substitution of intermediate tradable goods, while $A(h)$ and $A^*(h)$ involve terms related to the presence of price adjustment costs:

$$
\begin{aligned}
A_t(h) &\approx \kappa_H^p \frac{P_t(h)}{P_{t-1}(h)}\left(\frac{P_t(h)}{P_{t-1}(h)}-1\right) \\
&\quad -\beta\kappa_H^p \frac{P_{t+1}(h)}{P_t(h)}\left(\frac{P_{t+1}(h)}{P_t(h)}-1\right)\frac{Q_{H,t+1}}{Q_{H,t}} \\
A_t^*(h) &\approx \theta_T - 1 + \kappa_H^p \frac{P_t^*(h)}{P_{t-1}^*(h)}\left(\frac{P_t^*(h)}{P_{t-1}^*(h)}-1\right) \\
&\quad -\beta\kappa_H^p \frac{P_{t+1}^*(h)}{P_t^*(h)}\left(\frac{P_{t+1}^*(h)}{P_t^*(h)}-1\right)\frac{Q_{H,t+1}^*}{Q_{H,t}^*} \\
A_t^{**}(h) &\approx \theta_T - 1 + \kappa_H^p \frac{P_t^{**}(h)}{P_{t-1}^{**}(h)}\left(\frac{P_t^{**}(h)}{P_{t-1}^{**}(h)}-1\right) \\
&\quad -\beta\kappa_H^p \frac{P_{t+1}^{**}(h)}{P_t^{**}(h)}\left(\frac{P_{t+1}^{**}(h)}{P_t^{**}(h)}-1\right)\frac{Q_{H,t+1}^{**}}{Q_{H,t}^{**}}
\end{aligned}
$$

where κ_H^p,$\kappa_H^{p\,*}$,$\kappa_H^{p\,**} > 0$ respectively measure the degree of nominal rigidity in the Hom country, in the REA and in the RW. If nominal rigidities in the (domestic) export market are highly relevant (that is, if is relatively large), the degree of inertia of Home goods prices in the foreign markets will be high. If prices were flexible ($\kappa_H^p = \kappa_H^{p*} = \kappa_H^{p**} = 0$) then optimal price setting would be consistent with the cross-border law of one price (prices of the same tradable goods would be equal when denominated in the same currency).

5.3 Labor Market

In the case of firms in the intermediate nontradable sector, the labor input $L_N(n)$ is a CES combination of differentiated labor inputs supplied by domestic agents and defined over a continuum of mass equal to the country size ($j \in [0, s]$):

$$
L_{N,t}(n) \equiv \left(\frac{1}{s}\right)^{\frac{1}{\psi}} \left[\int_0^s L_t(n,j)^{\frac{\psi-1}{\psi}}\, dj\right]^{\frac{\psi}{\psi-1}} \tag{24}
$$

where $L(n, j)$ is the demand of the labor input of type j by the producer of good n and $\psi > 1$ is the elasticity of substitution among labor inputs. Cost minimization implies:

$$
L_t(n,j) = \left(\frac{1}{s}\right)\left(\frac{W_t(j)}{W_t}\right)^{-\psi} L_{N,t}(j), \tag{25}
$$

where $W(j)$ is the nominal wage of labor input j and the wage index W is:

$$
W_t = \left[\left(\frac{1}{s}\right)\int_0^s W_t(h)^{1-\psi}\, dj\right]^{\frac{1}{1-\psi}}. \tag{26}
$$

Similar equations hold for firms producing intermediate tradable goods. Each household is the monopolistic supplier of a labor input j and sets the nominal wage facing a downward-sloping

demand, obtained by aggregating demand across Home firms. The wage adjustment is sluggish because of quadratic costs paid in terms of the total wage bill:

$$AC_t^W = \frac{\kappa_W}{2}\left(\frac{W_t}{W_{t-1}} - 1\right)^2 W_t L_t \tag{27}$$

where the parameter $\kappa_W > 0$ measures the degree of nominal wage rigidity and L is the total amount of labor in the Home economy.

5.4 The equilibrium

We find a symmetric equilibrium of the model. In each country there is a representative agent and four representative sectorial firms (in the intermediate tradable sector, intermediate nontradable sector, consumption production sector and investment production sector). The equilibrium is a sequence of allocations and prices such that, given initial conditions and the sequence of exogenous shocks, each private agent and firm satisfy the correspondent first order conditions, the private and public sector budget constraints and market clearing conditions for goods, labor, capital and bond hold.

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