Structural reforms and zero lower bound in a monetary union

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Abstract

We assess the short-run macroeconomic effects of reforms to increase competition in the (nontradable) service sector when, in a monetary union, the monetary policy rate hits the zero lower bound (ZLB). We calibrate a large scale multi-country multi-sector dynamic general equilibrium model to a generic relatively large region of the euro area, the rest of the euro area and the rest of the world. Our results are as follows. First, reforms implemented unilaterally by one country do not affect the number of periods for which the ZLB holds and have short-run expansionary effects on domestic GDP. Second, reforms simultaneously implemented in whole euro area have short-run positive effects on output and reduce the time length of the ZLB, because higher economic activity raises inflation. Third, reforms have short-run expansionary effects even when they induce the ZLB to hold for a longer amount of time, because of their (positive) wealth effect, that more than counterbalances the (recessionary) substitution effect associated with the higher real interest rate. Finally, results are robust to alternative assumptions on the key parameters.

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1 Introduction

Structural reforms that increase the degree of competition in the product and labor market have recently been advocated as relevant policy options for several European countries that have been hardly hit by the financial and economic crises. As many countries in the euro area need to consolidate their public finances, fiscal policy is no longer an option to sustain growth; at the same time, a prolonged period of expansionary monetary policy has led the nominal interest rate close to the zero lower bound (ZLB). Pro-competition reforms can therefore become an appealing option for European policymakers.

Long-run macroeconomic benefits of structural reforms are clear and well documented in the literature.[1] 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 euro area-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 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 reform would reduce inflation and the monetary authority cannot reduce the policy rate. The reforms could therefore have negative macroeconomic effects on the country or the whole euro area.

In this paper we assess the short-run macroeconomic effects of reforms aimed at permanently increasing competition in the service sector in the euro area when the zero lower bound of monetary policy holds. The assessment is based on simulating a three-country large scale new-Keynesian dynamic general equilibrium model of a generic country member of the euro area (we call it "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).[2] The euro area 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 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-substituion (CES) production function that includes not only labor but also physical capital. Both factors

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

[2] 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 Coenen et al., 2008).

are supplied by domestic households in competitive markets. 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 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 in isolation, under alternative assumption for the zero lower bound. Subsequently, they are evaluated under the assumption that the reform is implemented simultaneously in the euro area as a whole. Also in this case, the case of a binding ZLB is considered.

Our results are as follows.

First, reforms implemented unilaterally by one country apart have short-run expansionary effects on domestic GDP and do not affect the number of periods for which the ZLB holds.

Second, reforms implemented in both regions of the the euro area have short-run expansionary effects on GDP. The ZLB holds for a lower amount of periods when reforms are implemented. **The interaction of different channels drives the result. The expectation of a permanently higher aggregate demand in the future leads firms to increase investment today (positive wealth effect). Higher expected future marginal costs drive current inflation up (through a forward-looking Phillips curve), which calls for a raise in the policy rate. The excess supply of services implies a EA real exchange rate depreciation, that gradually drives manufacturing goods' inflation up. Aggregate demand increases, also reflecting the complementarity of services and tradable goods in consumption. The combination of such factors more than counterbalances the negative intertemporal substitution effect on aggregate demand.**

Third, reforms have short-run expansionary effects even when they induce the ZLB to hold for a longer amount of time, because of a reduction in current inflation. Again, higher expected return on capital, that stimulates investment, and the favourable expenditure-switching effect, that favours domestic tradables, prevail on the negative intertemporal substitution effect.

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 macroeconomic impact 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 Eggertson et al. (2013), 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 and adjustment costs on main variables, we formalize the monetary union dimension of the euro area (instead of considering it

as a whole region) and its interaction with the rest of the world. As such, we fully characterize the role of trade and international relative price dynamics.

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. 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 of 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 $j^{**} \in (S; 1]$.[3]

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 the two final goods (consumption and investment goods) and monopolistic firms that produce the intermediate goods. The two 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 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

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

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.[4]

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.

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:

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

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 respectively the weights of EA CPI inflation rate ($\Pi_{EA,t}$) and GDP ($GDP_{EA,t}$). The CPI inflation rate is a geometric average of CPI inflation rates in the Home region and the REA (respectively Π_t and Π_t^*) 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 (respectively GDP_t and GDP_t^*):

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

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 beacause 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 effects of the structural reforms.

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 steady state, in each sector (manufacturing and service sectors) a first order condition for price

[4] See Rotemberg (1982).

setting like the following one 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. So, 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.

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:

$$E_0\left\{\sum_{t=0}^{\infty}\beta^t\left[\frac{\left(C_t(j) - hC_{t-1}\right)^{1-\sigma}}{(1-\sigma)} - \frac{L_t(j)^{1+\tau}}{1+\tau}\right]\right\} \tag{5}$$

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.[5] 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

[5] 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 households in the REA. See Benigno (2009).

because the two bundles have different composition.[6] 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:

$$K_t(j) = (1-\delta) K_{t-1}(j) + \left(1 - AC_t^I(j)\right) I_t(j) \tag{6}$$

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

$$AC_t^I(j) \equiv \frac{\phi_I}{2}\left(\frac{I_t(j)}{I_{t-1}(j)} - 1\right)^2,\ \phi_I > 0 \tag{7}$$

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 $W_t(j)$:

$$AC_t^W(j) \equiv \frac{\kappa_W}{2}\left(\frac{W_t(j)}{W_{t-1}(j)} - 1\right)^2 W_t L_t,\ \kappa_W > 0 \tag{8}$$

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. **We calibrate the parameters for the Home country to broadly replicate the features of a generic, relatively large region of the euro area. We set some parameter values so that steady-state ratios are consistent with 2010 national account data, which are the most recent and complete available data.** For remaining parameters we resort to previous studies and estimates available in the literature.[7]

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 Home and, in the REA and in the RW, to 0.46. The corresponding value in the production function of nontradables is set to 0.53 in Home and 0.43 in the REA and RW. In the final consumption and investment goods the

[6] See the Appendix for more details.

[7] Among others, see Forni et al. (2009, 2010a, 2010b).

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 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 Home, to 0.5 in the REA and the RW. For the investment basket, the bias towards the domestic tradeable is 0.50 in Home, 0.49 in the REA and 0.90 in the RW. The bias towards the composite tradable is 0.78 in Home, 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 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. This implies that for each region - in steady state - the net financial position of the private sector is equal to the public debt. The size of Home and REA GDPs, as a share of world GDP, are set to 3 percent and to 17 percent, respectively.[8]

[8] As for fiscal policy variables, the public consumption-to-GDP ratio is set to 0.20. The tax rate on wage

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 a negative (demand) persistent shock to worldwide private consumption and investment. The monetary policy rate in the euro area immediately hits the ZLB and stays at that level for 7 quarters. Thereafter, it gradually increases to reduce its negative difference with respect to its baseline level, following the decrease in the (negative) difference of inflation and GDP growth with respect 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.

On top of this recessionary scenario we simulate competition-friendly reforms. In one case they are implemented only in the Home country. In the other, simultaneously in the whole EA. In the case of Home country, the service sector (gross) markup is 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. We relax this assumption in the sensitivity analysis.

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 favours the increase in demand of capital and labor for production purposes. The reduction in prices 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. Employment also increases, by 1.5 percent. Home exports and imports increase, by 1.5 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

income τ^{ℓ} is set to 42.6 per cent in Home and to 34.6 in the REA. The tax rate on physical capital income τ^{k} is set to 34.9 in Home and 25.9 in the REA, while the tax rate on consumption τ^{c} is equal to 16.8 in Home and to 20.3 in the REA. The public debt-to-yearly GDP ratio is calibrated to 119 percent for Home and to 0.79 for the REA. Variables of the RW are set to values equal to those of corresponding REA variables.

real exchange rate depreciation. 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 rest of the EA 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 rest of the EA 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 GDP in the euro area increases by 2.5 percent. It is worthy to notice that 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 households and firms, that increase consumption and investment and, hence, imports. Home exports increase relatively more, favoured by the increase in aggregate demand in the REA.

Finally column (c) shows the case of a unilateral reduction of the Home markup by 5 p.p. (instead of 10 p.p.). Results do not change qualitatively. Their size is half as much that obtained under the 10 p.p. unilateral reduction (column a), suggesting that there are no large nonlinearities in the transmission mechanism of the markup shock.

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

3.3 Short-run effects and the ZLB

The previous section shows 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 point is to evaluate if the reforms (1) improve the short-run macroeconomic performance of country members under the ZLB and (2) allow the EA economy to get out of the ZLB faster than it would otherwise do.

3.3.1 Unilateral Home implementation

Figure 1 shows the macroeconomic effects of the competition reform in the Home service sector (continuous line). The short-run GDP decrease is slightly lower than the one obtained when it is only the negative world-wide aggregate demand shock to hit the Home economy (red dashed line). 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, 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, favoured by the Home real exchange rate depreciation to favour the absorption of the excess supply of Home goods and services.[9]

There are differences in the medium run, when reforms are fully implemented. GDP increases relatively more when the reforms are enacted than in the ZLB scenario. The additional increase is driven by investment, labor and consumption.

Overall, Home unilateral implementation of reforms on top of a worldwide recession and a binding ZLB slightly improve the Home short-run macroeconomic outlook. 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, as 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 rest of the EA service sector is gradually decreased by 10 percentage points over a five-year period. Economic activity increases in the short run in the whole euro area. Crucially, both the Home and REA economies get out of the ZLB immediately. The reason is that euro area inflation decreases to a lower extent than in the ZLB scenario. Firms anticipate that, because of reforms, aggregate demand will increase in the future to a larger extent and on a permanent basis. **Such positive and large wealth effect reflects the presence of capital accumulation in the model economy.** Moreover, future marginal cost will increase as well, because firm will demand more labor and capital to sustain the higher production level. As the Phillips curve is forward-looking, the expected stream of future high marginal costs constitute a positive impulse for the current inflation level, that at least partially counterbalances the negative impulse associated with the decrease in aggregate demand **(the latter being the result of a negative intertemporal substitution effect)**. This is true in particular for (tradable) manufacturing goods. Demand for domestic and imported manufacturing goods increases because of the complementarity relationship 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. For imported goods, the excess supply of services implies the EA real exchange rate depreciation, that 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. Inflation decreases to a lower extent than in the ZLB scenario. This implies that the monetary policy rate gets out of the ZLB sooner under the reform scenario

[9] Spillover effects to the rest of the EA, not reported to save on space, are small.

than in the case of no reforms. It gradually moves to its baseline level, following the gradual return of inflation rate and the economic activity towards their corresponding benchmark values.

For real variables, EA consumption, labor and, in particular, investment, increase relatively to their corresponding ZLB values, because the gradual kick-in of the reform favours a quicker increase in aggregate demand and economic activity. The difference between the corresponding variables in the ZLB and reform scenarios increases as time goes by.

In comparison to 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 Timing AND CREDIBILITY (?) of reforms

To further assess the role of expected income and return on capital in driving the results reported in the previous section, we initially evaluate the role of the speed in implementing the reforms, assuming that the reform is fully implemented in the initial quarter and not in a gradual fashion. Thereafter, we assume that households anticipate that the increase in competition lasts only for (initial) five years and thereafter the degree of competition returns to its initial level, i.e. households do not believe that the reform is permanent. 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 under the assumption that reforms are fully implemented in quarter one ("sudden implementation"). This corresponds to an immediate markup decrease to its new long run level in both Home and the REA. In the benchmark case 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. GDP response is rather similar across the two scenarios. The short-run improvement in economic activity is larger under the sudden implementation (green dotted line), as there is a larger incentive for firms to immediately increase capital and, hence, demand for investment. More importantly, **GDP increases DECREASES LESS** even if the ZLB lasts for a longer amount of time under the sudden implementation. In the latter case inflation is lower than in the benchmark case of gradual implementation **and in the ZLB case**, inducing the monetary policy rate to stay at the zero level for more periods than under the ZLB scenario. 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 effect of higher future discounted marginal costs is lower, since the reform is expected to last for less periods. As a result, the effect on current inflation is smaller.** 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 **intertemporal substitution** effect associated with the increase in the expected real interest rate.

3.4.2 Temporary decrease in markups

Figure 5 reports results when markups in the service sector are reduced only temporarily. The markup gradually decreases by 10 percentage points during the initial five years. Differently from the benchmark scenario, from the sixth year the markups immediately returns to its initial level. This scenario can be interpreted as households not believing that the reform is permanent (hence the reform is not fully credible) for some unmodeled reason. As such, households anticipate that the markup reduction is temporary.

Temporary reforms continue to have a short-run expansionary effect on GDP (green dotted line). It is smaller than in the benchmark case mainly because the incentive to increase investment is now lower and, hence, aggregate demand increases less than supply in the short run, contributing to further reduce inflation. This implies that the ZLB holds for a longer amount of time when the reform is short-lived. As in previous simulations, economic activity is driven up by the expected return on capital and a positive income effect. They are relatively muted with respect to the previous scenarios, but they are still able to counterbalances the recessionary effect of the higher real interest rate.

4 Sensitivity analysis

We report results of the sensitivity analysis. We initially consider the case of the (permanent) reforms implemented in correspondence of higher adjustment costs on investment and, thereafter, in correspondence of high price stickiness for exported and imported goods.

4.1 Higher adjustment costs on capital

We double the value of adjustment costs on investment in the euro area (from 6 to 12). Figure 6 shows the results. Overall, they do not greatly change relatively to the benchmark case. Short-run GDP **increases (DECREASES LESS)** relatively to the case of the ZLB. The **increase (EXPANSIONARY EFFECT)** 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, **the increase in inflation relative to the ZLB case is smaller than in**

the benchmark case. However, the relative increase is large enough to favour 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), so 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, **GDP increases** and the monetary policy rate decreases to a lower extent.

5 Conclusions

We have evaluated the short-run macroeconomic effects of implementing structural (supply-side) reforms in the euro area when the ZLB holds. Our results suggest that reforms stimulate short-run euro area economic activity when simultaneously implemented across country members of the euro area. The increase in GDP is associated with the increase in demand for investment and in net exports. Higher investment is favoured by the expected future permanent increase in production. Higher net exports are due to the real exchange rate depreciation, as the overall supply of goods produced in the euro area increases. Moreover, reforms tend to reduce the length of the ZLB, as the higher aggregate demand favours the increase in prices of tradable goods. Finally, reforms implemented by one country member apart have short-run expansionary effects, but they do not affect the length of the ZLB.

Overall, our results suggest that structural reforms, aimed at increasing the potential output (and hence income) of the euro area, are beneficial in the short run also when the ZLB holds.

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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; source: OECD (2012).

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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

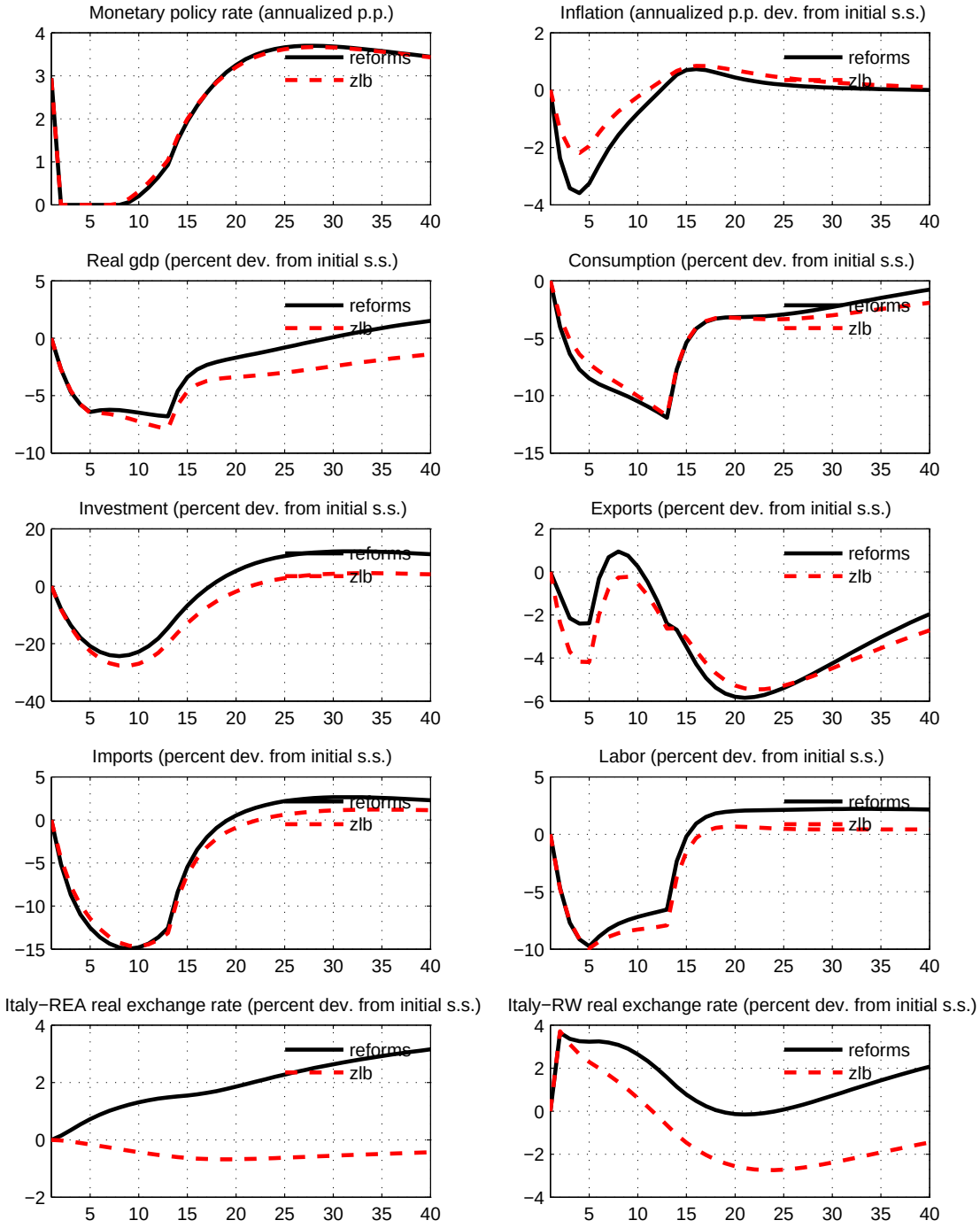
Note: REA= Rest of the euro area; RW= Rest of the world. Sources: European Commission (2012b).

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

	(a) services	(b) EA services reform	(c) services reform (5 p.p.)
Home			
GDP	3.21	3.29	1.57
Consumption	1.62	1.83	0.82
Investment	5.06	5.28	2.47
Exports	1.38	1.53	0.68
Imports	0.45	0.89	0.22
Labor	1.55	1.53	0.76
Real exch. rate (vis--vis REA)	3.99	-0.76	1.96
Real exch. rate (vis--vis RW)	3.98	4.10	1.96
Terms of trade (vis--vis REA)	0.93	0.24	0.46
Terms of trade (vis--vis RW)	0.91	0.99	0.45
Rest of euro area			
GDP	0.03	2.48	

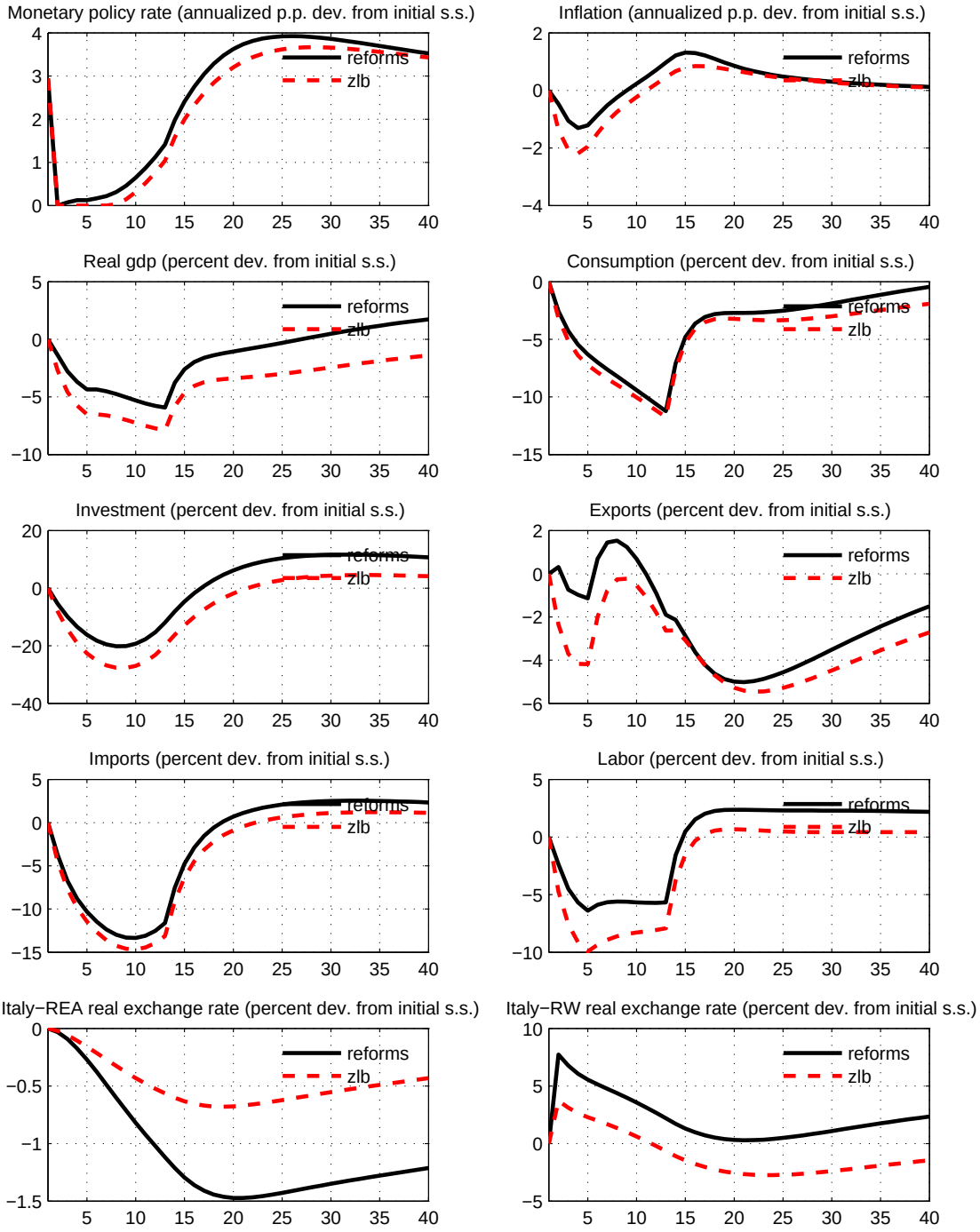
Note: % deviations from initial steady state. For real exchange rate, +=depreciation, for terms of trade +=deterioration.

Figure 1. Increasing competition in the Italian service sector



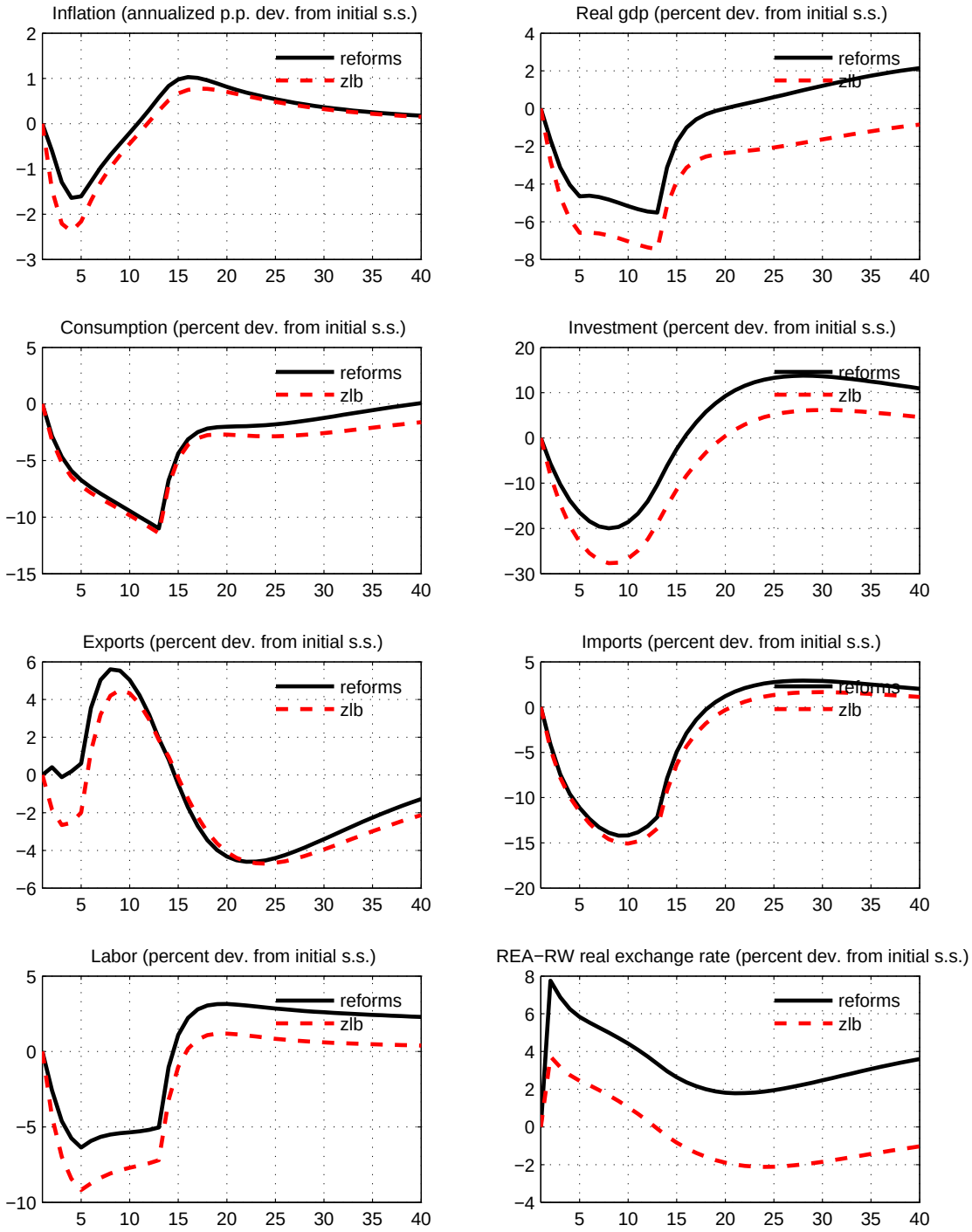
Note. Horizontal axis: years

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



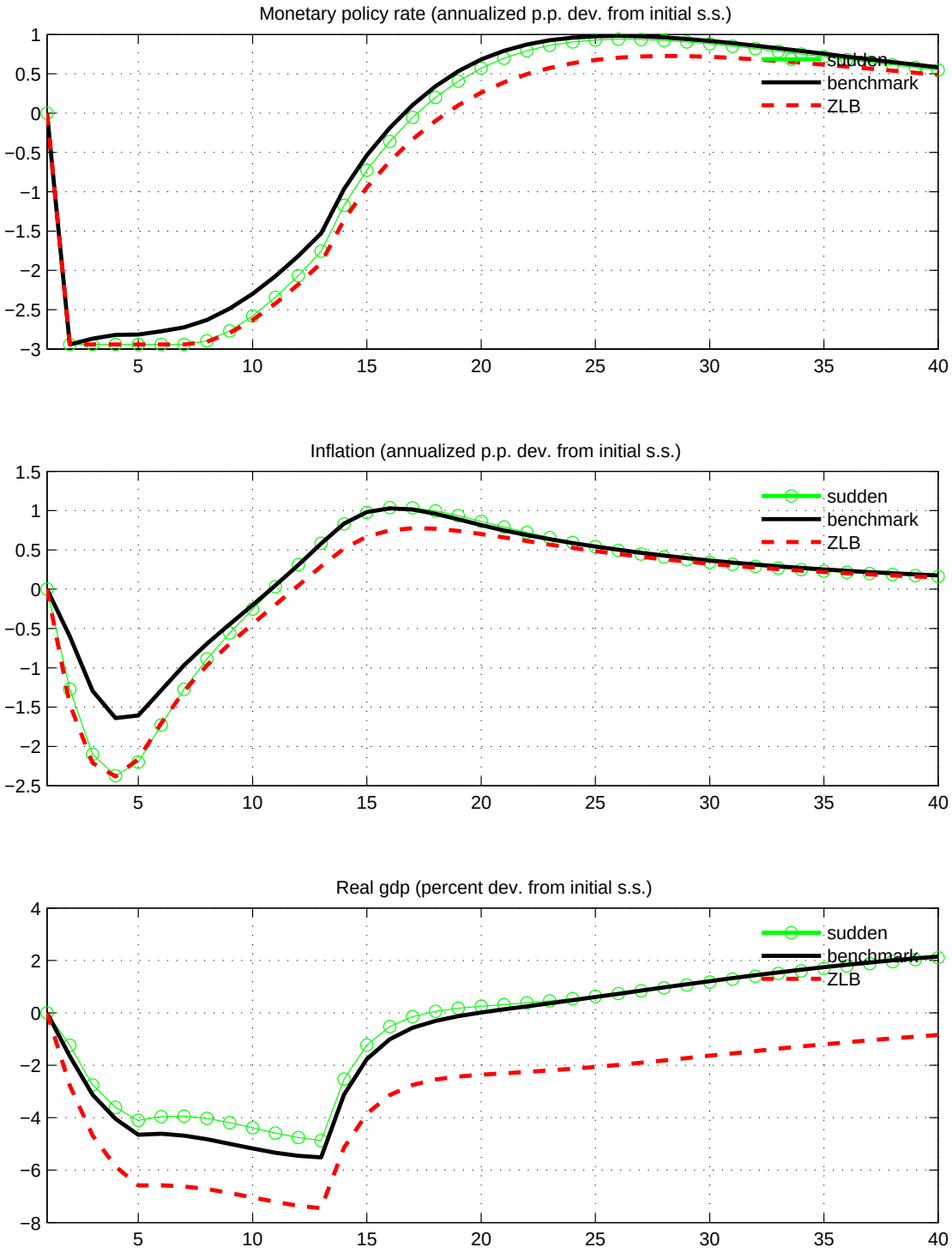
Note. Horizontal axis: years

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



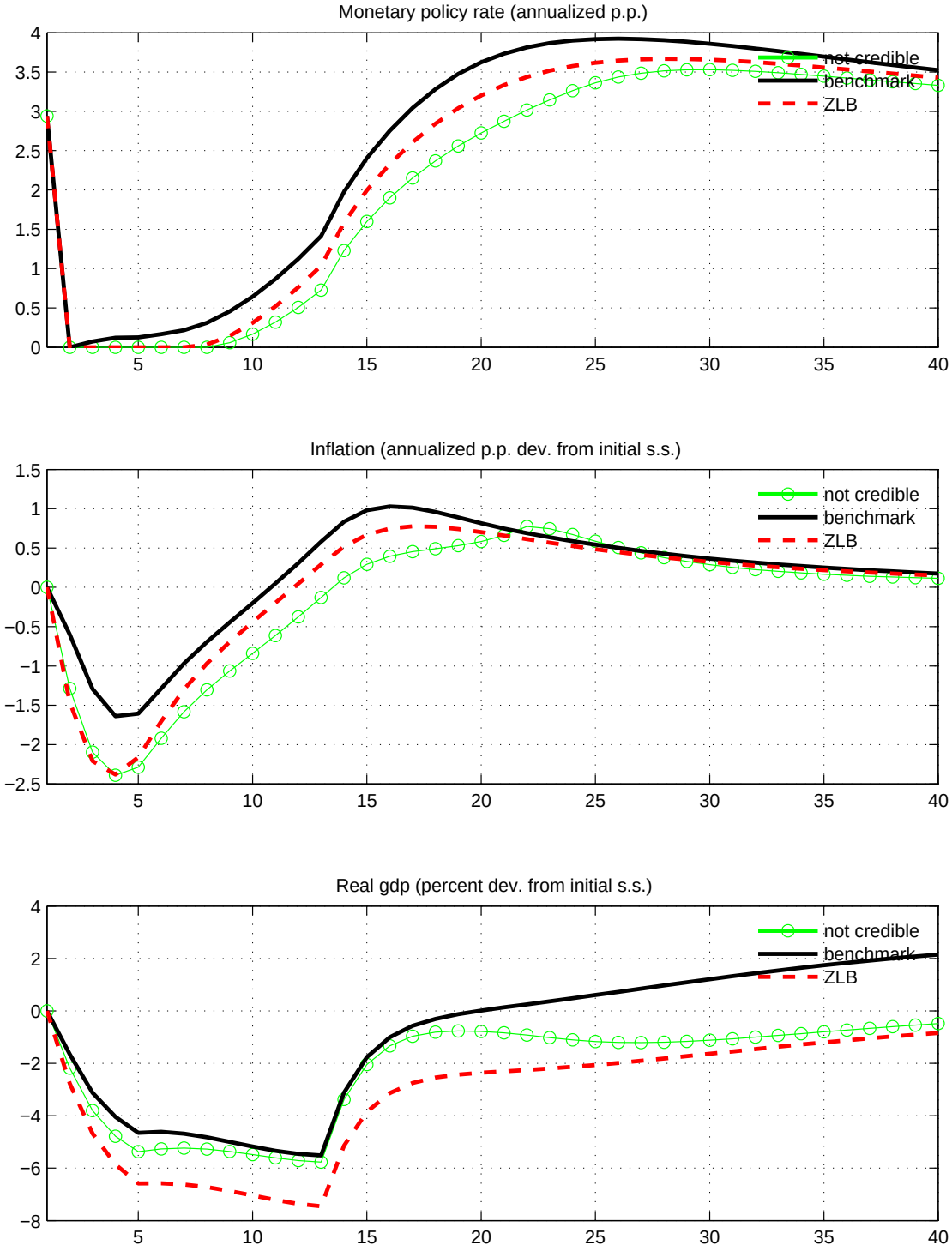
Note. Horizontal axis: years

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



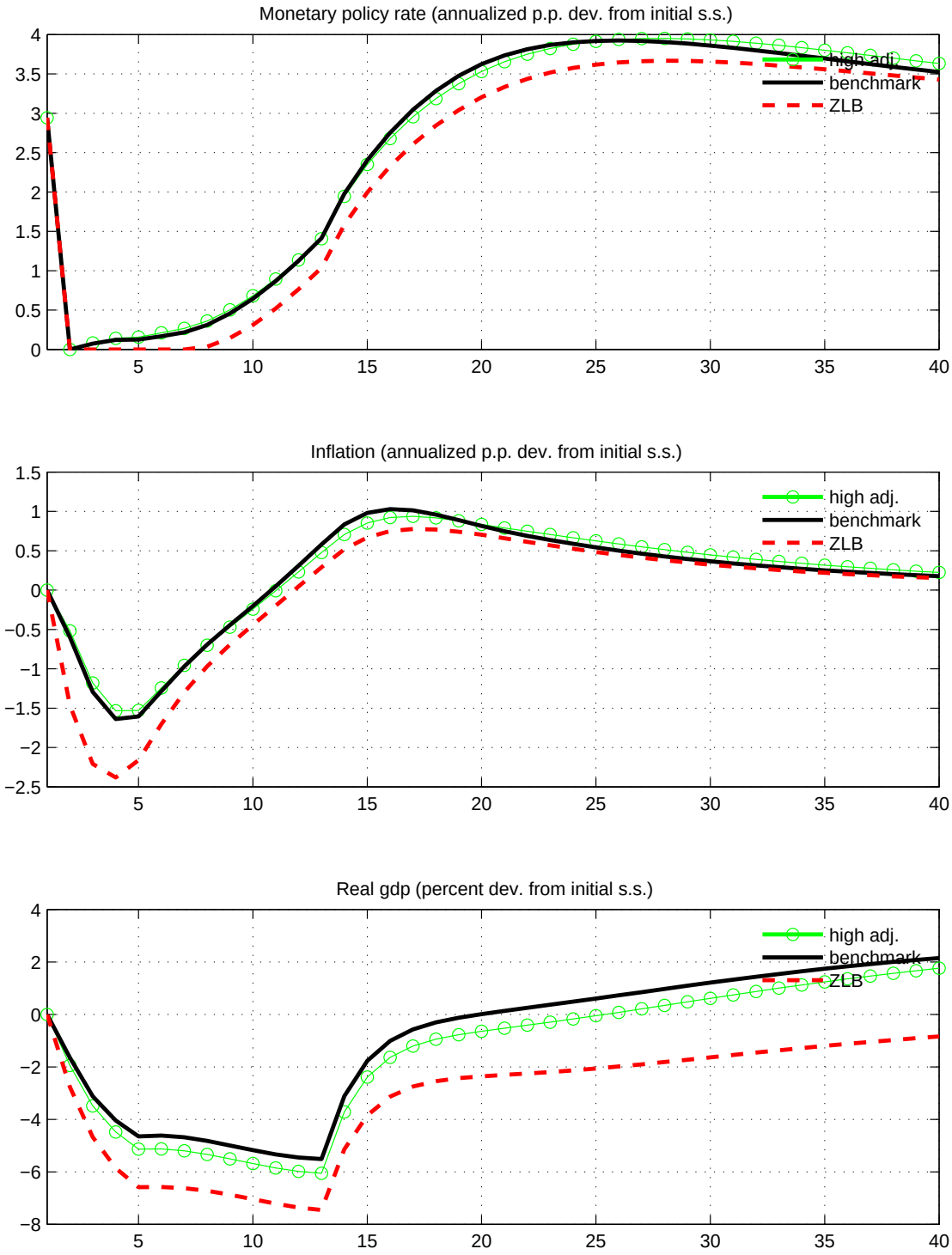
Note. Horizontal axis: years

Figure 5. Transitory increase in competition in the EA service sector. REA variables



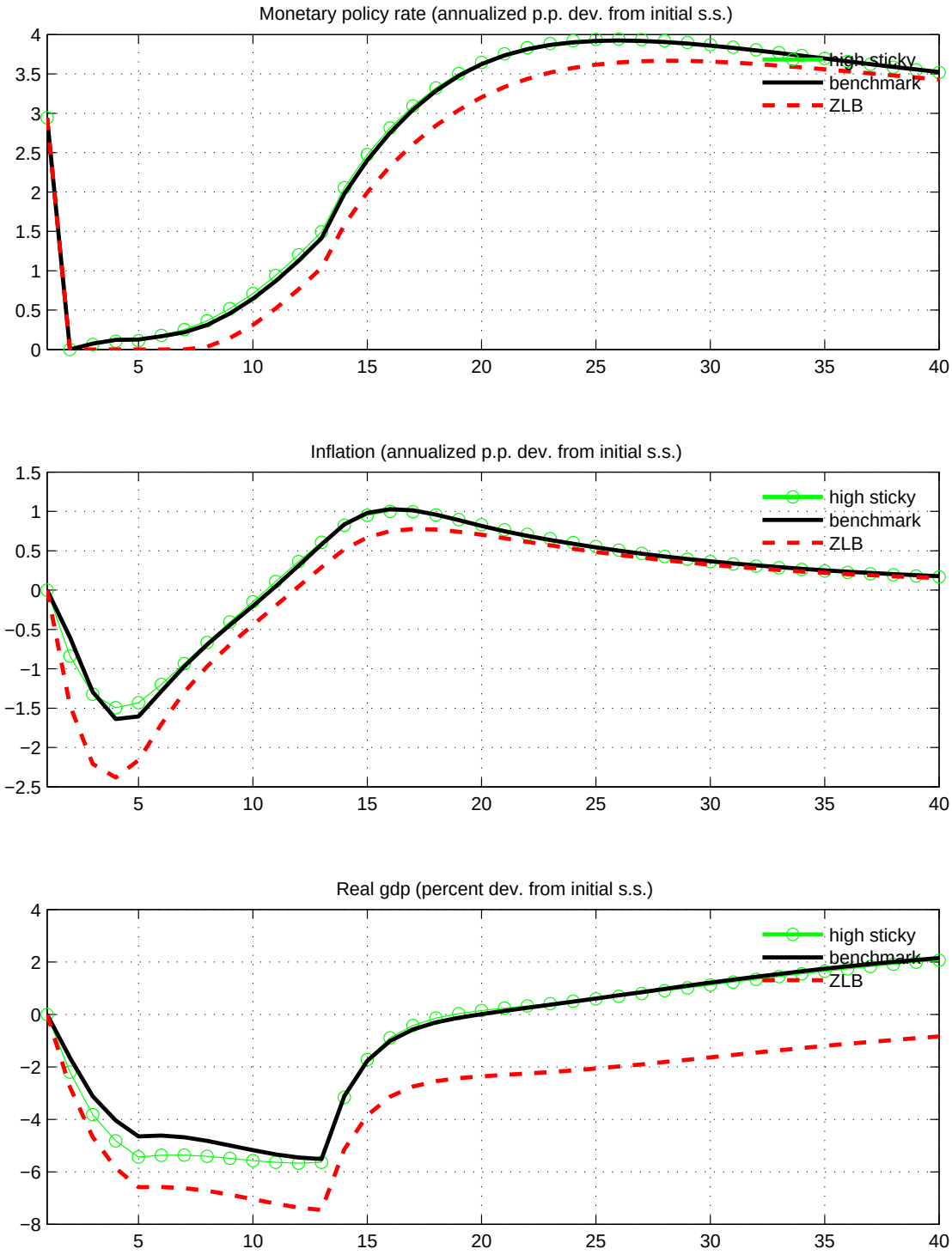
Note. Horizontal axis: years

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



Note. Horizontal axis: years

Figure 7. Sensitivity. High price stickiness. REA variables



Note. Horizontal axis: years

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.[10]

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.

[10] 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:

$$Q_{HA}(x) \equiv \left[\left(\frac{1}{s}\right)^{\theta_T}\int_0^s Q(h,x)^{\frac{\theta_T-1}{\theta_T}}\,dh\right]^{\frac{\theta_T}{\theta_T-1}} \tag{9}$$

$$Q_{GA}(x) \equiv \left[\left(\frac{1}{S-s}\right)^{\theta_T}\int_s^S Q(g,x)^{\frac{\theta_T-1}{\theta_T}}\,dg\right]^{\frac{\theta_T}{\theta_T-1}} \tag{10}$$

$$Q_{FA}(x) \equiv \left[\left(\frac{1}{1-S}\right)^{\theta_T}\int_S^1 Q(f,x)^{\frac{\theta_T-1}{\theta_T}}\,df\right]^{\frac{\theta_T}{\theta_T-1}} \tag{11}$$

$$Q_{NA}(x) \equiv \left[\left(\frac{1}{s}\right)^{\theta_N}\int_0^s Q(n,x)^{\frac{\theta_N-1}{\theta_N}}\,dn\right]^{\frac{\theta_N}{\theta_T-1}} \tag{12}$$

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:

$$Q_{A,t}(n,x) = \left(\frac{1}{s}\right)\left(\frac{P_t(n)}{P_{N,t}}\right)^{-\theta_N} Q_{NA,t}(x) \tag{13}$$

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

$$P_{N,t} = \left[\int_0^s P_t(n)^{1-\theta_N}\,dn\right]^{\frac{1}{1-\theta_N}} \tag{14}$$

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 $N^S(n)$:

$$N_t^S(n) = \left((1-\alpha_N)^{\frac{1}{\xi_N}} L_{N,t}(n)^{\frac{\xi_N - 1}{\xi_N}} + \alpha^{\frac{1}{\xi_N}} K_{N,t}(n)^{\frac{\xi_N - 1}{\xi_N}} \right)^{\frac{\xi_N}{\xi_N - 1}} \tag{15}$$

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:

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

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

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

$$MC_{N,t}(n) = \left((1-\alpha) W_t^{1-\xi_N} + \alpha \left(R_t^K \right)^{1-\xi_N} \right)^{\frac{1}{1-\xi_N}} \tag{17}$$

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:

$$p_t(n) = \frac{\theta_N}{\theta_N - 1} mc_t(n) - \frac{A_t(n)}{\theta_N - 1} \tag{18}$$

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):

$$p_t(n) = \frac{\theta_N}{\theta_N - 1} mc_{N,t}(n) \tag{19}$$

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:

$$p_t(h) = \frac{\theta_T}{\theta_T - 1} mc_t(h) - \frac{A_t(h)}{\theta_T - 1} \tag{20}$$

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

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

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 ($j \in [0, s]$):

$$
L_{N,t}(n) \equiv \left(\frac{1}{s}\right)^{\frac{1}{\psi}} \left[\int_0^s L_t(n,j)^{\frac{\psi-1}{\psi}}\, dj\right]^{\frac{\psi}{\psi-1}} \tag{23}
$$

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:

$$
L_t(n,j) = \left(\frac{1}{s}\right)\left(\frac{W_t(j)}{W_t}\right)^{-\psi} L_{N,t}(j), \tag{24}
$$

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

$$
W_t = \left[\left(\frac{1}{s}\right)\int_0^s W_t(h)^{1-\psi}\, dj\right]^{\frac{1}{1-\psi}}. \tag{25}
$$

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:

$$AC_t^W = \frac{\kappa_W}{2}\left(\frac{W_t}{W_{t-1}} - 1\right)^2 W_t L_t \tag{26}$$

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.