Online Appendix to "Market Reforms at the Zero Lower Bound"

Not For Publication

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A Wage Determination

Consider a worker with idiosyncratic productivity z. The sharing rule implies:

$$\eta\Delta_t^F(z) = (1-\eta)\Delta_t^W(z), \tag{11}$$

where $\Delta_t^W(z)$ and $\Delta_t^F(z)$ denote, respectively, worker's and firm's real surplus, and η is the worker's bargaining weight. The worker's surplus is given by

$$\Delta_t^W(z) = w_t(z) - \varpi_t + E_t\tilde{\beta}_{t,t+1}\left(1 - G\left(z_{t+1}^c\right)\right)\tilde{\Delta}_{t+1}^W, \tag{12}$$

where $\tilde{\beta}_{t,t+1} \equiv (1-\lambda)\,\beta_{t,t+1}$, and

$$\tilde{\Delta}_t^W \equiv \left[1 - G\left(z_t^c\right)\right]^{-1}\int_{z_t^c}^{\infty}\Delta_t^W(z)g(z)dz$$

represents the average surplus accruing to the worker when employed in firm . The term ϖ_t is the worker's outside option, defined in the text:

$$\varpi_t \equiv h_p + b_t + \iota_t E_t\left[\tilde{\beta}_{t,t+1}\left(1 - G\left(z_{t+1}^c\right)\right)\tilde{\Delta}_{t+1}^W\right].$$

The firm surplus corresponds to the value of the job to the firm, $J_t(z)$, plus savings from firing costs F, i.e., $\Delta_t^F(z) = J_t(z) + F_t$—as pointed out by Mortensen and Pissarides (2002), the outside option for the firm in wage negotiations is firing the worker, paying firing costs. The value of the job to the firm corresponds to the revenue generated by the match, plus its expected discounted continuation value, net of the cost of production (the wage bill and the rental cost of capital):

$$J_t(z) = \varphi_t Z_t z k_t^{\alpha}(z) - w_t(z) - r_t^K k_t(z) + E_t\tilde{\beta}_{t,t+1}\left[\left(1 - G\left(z_{t+1}^c\right)\right)\tilde{\Delta}_{t+1}^F - G\left(z_{t+1}^c\right)F_{t+1}\right],$$

where $\tilde{\Delta}_t^F \equiv \left[1 - G\left(z_t^c\right)\right]^{-1}\int_{z_t^c}^{\infty}\Delta_t^F(z)g(z)dz$ corresponds to the Lagrange multiplier ψ_t in the firm profit maximization.

For each job, the producer equates the marginal revenue product of capital to its rental cost:

$$\alpha\varphi_{\omega t}Z_t z k_{\omega t}^{\alpha-1}(z) = r_t^K. \tag{13}$$

Let $\tilde{k}_{\omega t} \equiv \left[1 - G\left(z_{\omega t}^c\right)\right]^{-1}\int_{z_{\omega t}^c}^{\infty}k_{\omega t}(z)\,g(z)dz$ be the average capital stock per worker. Equation (13)

implies:

$$\tilde{k}_{\omega t} = \left(\frac{r_t^K}{\alpha \varphi_{\omega t} Z_t} \right)^{\frac{1}{\alpha - 1}} \tilde{z}_{\omega t}^{\frac{1}{1-\alpha}}, \tag{14}$$

where $\tilde{z}_{\omega t}$ is defined as in the main text: $\tilde{z}_{\omega t} \equiv \left[\int_{z_{\omega t}^c}^{\infty} z^{1/(1-\alpha)} \frac{g(z)}{1-G(z_{\omega t}^c)} dz \right]^{1-\alpha}$. Let $\psi_{\omega t}$ be the Lagrange multiplier on the constraint $l_{\omega t} = (1 - \lambda_{\omega t}) (l_{\omega t-1} + q_{t-1} v_{\omega t-1})$, corresponding to the average marginal revenue product of a job. The first-order condition for $v_{\omega t}$ and $l_{\omega t}$ imply, respectively:

$$\frac{\kappa}{q_t} = E_t \left\{ \tilde{\beta}_{t,t+1} \left[(1 - G\left(z_{\omega t+1}^c\right)) \psi_{\omega t+1} - G\left(z_{\omega t+1}^c\right) F_{t+1} \right] \right\}, \tag{15}$$

$$\psi_{\omega t} = \varphi_{\omega t} \frac{y_{\omega t}}{l_{\omega t}} - \tilde{w}_{\omega t} - r_t^K \tilde{k}_{\omega t} + \frac{\kappa}{q_t}, \tag{16}$$

By combining equations (13) and (14), we obtain

$$k_{\omega t}(z) = \tilde{k}_{\omega t} \left(\frac{z}{\tilde{z}_{\omega t}} \right)^{\frac{1}{1-\alpha}}. \tag{17}$$

Using equations (13), (17), and (16), $J_t(z)$ can then be written as

$$J_t(z) = \pi_t(z) - w_t(z) + \frac{k}{q_t}. \tag{18}$$

where

$$\pi_t(z) \equiv (1 - \alpha) \varphi_t \frac{y_t}{l_t} \left(\frac{z}{\tilde{z}_t} \right)^{1/(1-\alpha)}$$

denotes the marginal revenue product of the worker. Therefore, the firm surplus is equal to

$$\Delta_t^F(z) = \pi_t(z) - w_t(z) + \frac{k}{q_t} + F_t. \tag{19}$$

Since the sharing rule in (11) implies that $\tilde{\Delta}_t^W = \tilde{\Delta}_t^F \eta/(1-\eta)$, the worker surplus can be written as:

$$\Delta_t^W(z) = w_t(z) - \varpi_t + \frac{\eta}{1-\eta} E_t \left\{ \tilde{\beta}_{t,t+1} \left[1 - G\left(z_{t+1}^c\right) \right] \left(\tilde{J}_{t+1}(z) + F_{t+1} \right) \right\}.$$

Using equation (15), we obtain:

$$\Delta_t^W(z) = w_t(z) - \varpi_t + \frac{\eta}{1-\eta} \left[\frac{\kappa}{q_t} + E_t \left(\tilde{\beta}_{t,t+1} F_{t+1} \right) \right]. \tag{20}$$

Inserting equations (19) and (20) into the sharing rule (11), we finally obtain:

$$w_t(z) = \eta \left\{ \pi_t(z) + F_t - (1-\lambda) E_t \beta_{t,t+1} F_{t+1} \right\} + (1-\eta) \varpi_t.$$

The average wage $\tilde{w}_t$ is then given by

$$\tilde{w}_t = \eta \left\{ \tilde{\pi}_t + F_t - (1-\lambda) E_t \beta_{t,t+1} F_{t+1} \right\} + (1-\eta) \varpi_t. \tag{21}$$

Finally, notice that in the symmetric equilibrium the worker outside option reduces to:

$$\varpi_t \equiv h_p + b_t + \frac{\eta}{1-\eta} \left[\kappa \vartheta_t + \iota_t E_t \left(\tilde{\beta}_{t,t+1} F_{t+1} \right) \right].$$

Therefore, in equilibrium, the average wage is given by:

$$\tilde{w}_t = \eta \left[\tilde{\pi}_t + \kappa \vartheta_t + F_t - (1-\lambda)(1-\iota_t) E_t \beta_{t,t+1} F_{t+1} \right] + (1-\eta)(h_p + b_t).$$

B Calibration: Additional Details

Regulation in the Euro Area: Core and Periphery

Table A.1 presents data on product and labor market regulation in core and periphery euro area countries.

Calibration of Red Tape Costs

Ebell and Haefke (2009) estimate the regulation cost of market entry for 17 advanced countries in the year 1997. They measure the average number of months of output lost due to administrative delays and fees. Data about administrative delays are taken from the Logotech S.A dataset, as reported by the OECD's 1998 "Fostering Entrepreneurship" Report and Pissarides (2003). Data on entry fees come from Djankov, Porta, Lopez-De-Silanes, and Shleifer (2002).

In the absence of more recent estimates, and in order to capture various product market reforms carried out in most advanced economies since 1997, we update the Ebell and Haefke's measure for 2013 by making use of the OECD's barriers to entrepreneurship indicators, which are available for the years 1998 and 2013 (see Koske, Wanner, Bitetti, and Barbiero, 2014 for details). The index, measured on a 0-6 scale, measures "administrative burdens on start-ups", capturing both delays

and fees.

Our procedure is the following. First, for the year 1997, we regress the log of total entry costs in Ebell and Haefke (2009) on the OECD indicator of administrative burdens on start-up. The implied coefficient is 0.854 with a $t-stat$ of 4.87 corresponding to a correlation coefficient of 0.78. The constant term is -1.345. Not surprisingly, there is a very strong correlation between Ebell and Haefke's quantitative estimate of total entry costs and the OECD indicator.[33] Next, we then plug the numerical value of the OECD's indicator for 2013 into this regression, obtaining an updated estimate of Ebell and Haefke's total entry costs for each country in 2013.

Finally, we compute the relevant cross-country averages to calibrate the average value of regulatory entry costs. We consider a weighted average of the index values across euro area member countries, with weights equal to the contributions of individual countries' GDPs to euro area total GDP.

Historical Taylor Rule for the Euro Area

Here we consider an alternative calibration of the Taylor rule that uses historical euro-area estimates from Gerdesmeier and Roffia (2003). We set the inflation and GDP gap weights equal to 1.93 and 0.075, respectively, and the smoothing parameter equal to 0.87. Table 2 presents the second moments for this alternative calibration. The model continues to account for the cyclical behavior of real variables. In addition, it accounts for the relative volatility of the interest rate and inflation, as well as their comovement with GDP.

C Additional Impulse Responses for the Baseline Model

Productivity Shock

Figure A.1 plots impulse responses following a one standard deviation, negative productivity shock. The shock results in higher inflation and unemployment; output, consumption, and investment decline. The central bank reacts to the inflationary shock by increasing the interest rate, which further contributes to the drop in aggregate demand and output.

[33] Interestingly, there is no statistically significant cross-country correlation between Ebell and Haefke's estimate and the other components of the OECD's barriers to entrepreneurship indicators, such as "complexity of regulatory procedures" and "regulatory protection of incumbents". This clearly indicates that the "administrative burdens on start-ups" component does indeed capture firm entry costs.

Home Production

Figure A.2 plots impulse responses following a permanent decline in home production.

Exogenous Price-Markup Reduction

Figure A.3 plots impulse responses following a permanent decline in the price markup.

Pair of Market Reforms

Figure A.4-A.6 study the effects of pairs of market reforms (product market and unemployment benefits; product market and firing costs; unemployment benefits and firing costs). The figures show a reform that jointly lowers barriers to entry and unemployment benefits leads to the largest short-run increase in output, both in normal times and at the ZLB. This happens since, unlike a full package of simultaneous reforms in the three areas covered in the paper, a package of reforms that focuses only on product markets and unemployment benefits is not undermined by the short-run contractionary effects of lowering firing costs.

D The Effects of Market Reforms With Input-Output Linkages

Figure A.7-A.10 present impulse response for product and labor market reforms (including joint deregulation) for the model that features input-output linkages.

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TABLE A.1: REGULATION IN THE EURO AREA

	Core	Periphery
Product Market Regulation, OECD Regulation Index Retail Industry, 2013	2.58	2.94
Unemployment Benefits, Gross Replacement Rate, 2013	29.4	34.9
Employment Protection Legislation, OECD Index, 2013	2.59	2.34

TABLE A.2: SECOND MOMENTS, HISTORICAL TAYLOR RULE

	Data	Model
Output	$\sigma_Y = 1.18$	$\sigma_Y = 1.18$
Consumption	$\sigma_C = 0.52$	$\sigma_C = 0.57$
Investment	$\sigma_I = 2.74$	$\sigma_I = 2.74$
Employment	$\sigma_L = 0.57$	$\sigma_L = 0.58$
Wages	$\sigma_w = 0.29$	$\sigma_w = 0.84$
Inflation	$\sigma_\pi = 0.21$	$\sigma_\pi = 0.23$
Interest Rate	$\sigma_\iota = 0.57$	$\sigma_\iota = 0.57$
Consumption	$corr\,(C_t, Y_t) = 0.97$	$corr\,(C_t, Y_t) = 0.81$
Investment	$corr\,(I_t, Y_t) = 0.69$	$corr\,(I_t, Y_t) = 0.93$
Employment	$corr\,(L_t, Y_t) = 0.96$	$corr\,(L_t, Y_t) = 0.97$
Wages	$corr\,(w_t, Y_t) = 0.93$	$corr\,(w_t, Y_t) = 0.94$
Inflation	$corr\,(\pi_t, Y_t) = 0.82$	$corr\,(\pi_t, Y_t) = 0.75$
Interest Rate	$corr\,(i_t, Y_t) = 0.19$	$corr\,(i_t, Y_t) = 0.69$

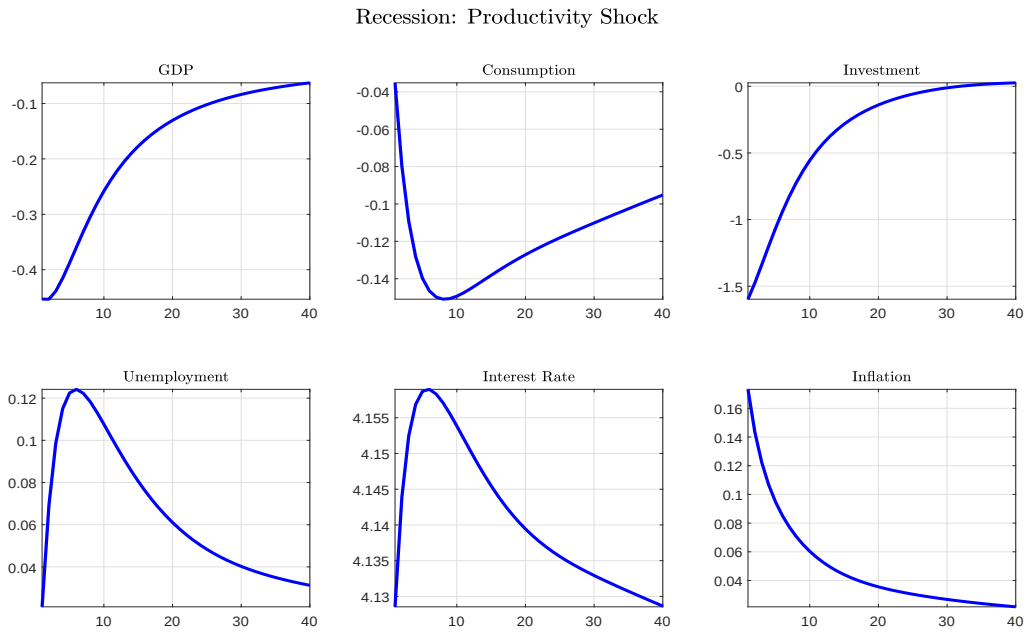

Figure A.1. Negative, one standard deviation productivity shock with high regulation. Responses show percentage deviations from the steady state. Unemployment is in deviations from the steady state. The inflation and interest rates are annualized and expressed in percentage points.

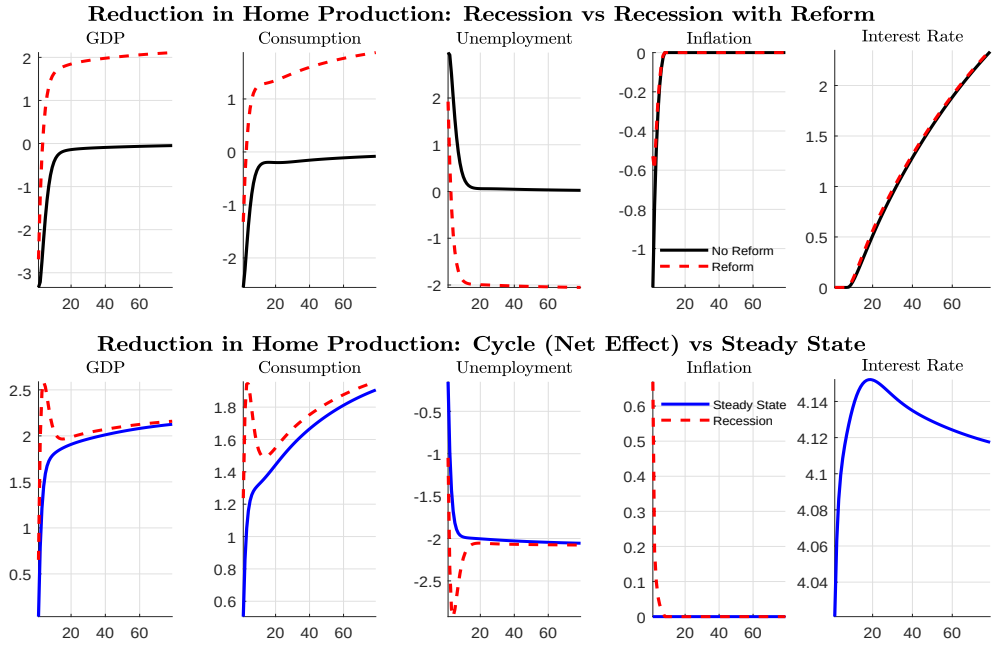

Figure A.2. *Top panel:* recession (continuous lines) versus recession followed by a reduction in home production (dashed lines); *Bottom panel*: net effect of a home production reduction in normal times (continuous lines) and in a recession with binding ZLB (dashed lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state. The inflation and interest rates are annualized and expressed in percentage points.

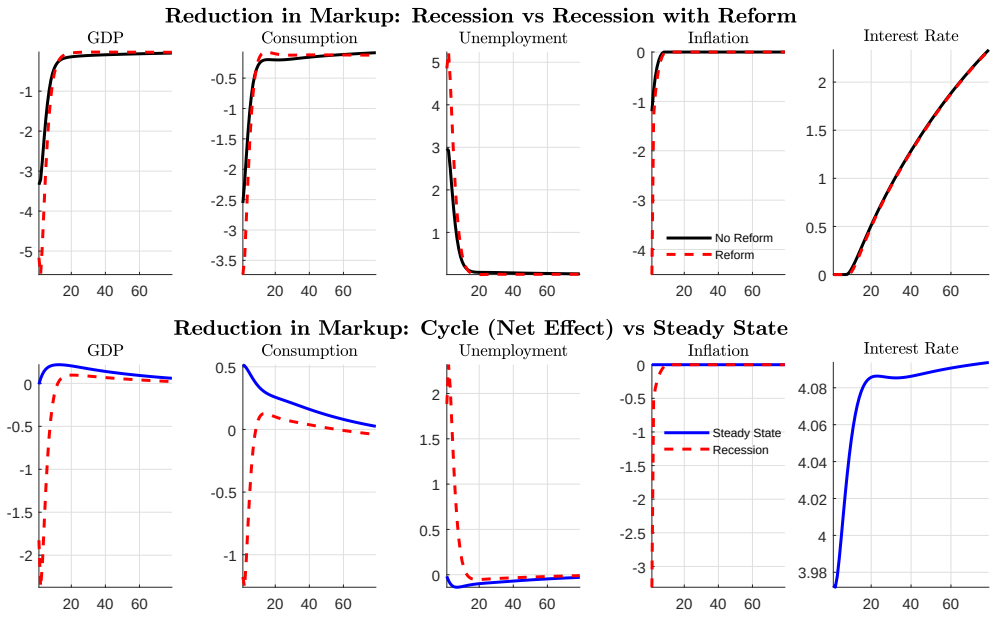

Figure A.3. *Top panel:* recession (continuous lines) versus recession followed by an exogenous reduction in the price markup (dashed lines); *Bottom panel*: net effect of the exogenous price markup reduction in normal times (continuous lines) and in a recession with binding ZLB (dashed lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state. The inflation and interest rates are annualized and expressed in percentage points.

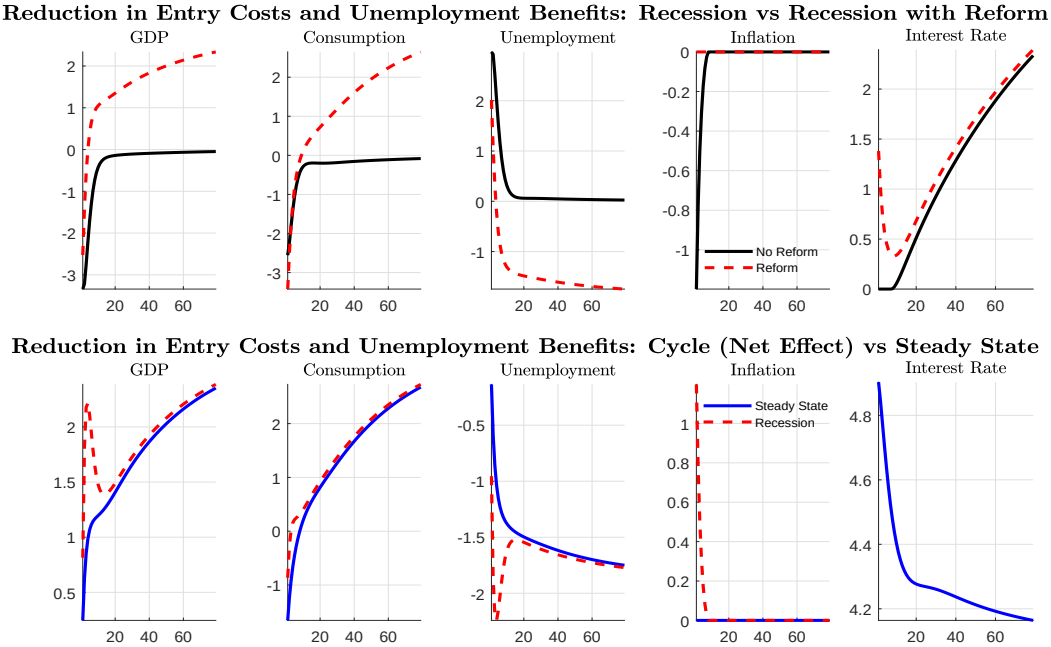

Figure A.4. *Top panel:* recession (continuous lines) versus recession followed by a reduction in barriers to entry and unemployment benefits (dashed lines); *Bottom panel*: net effect of product market and unemployment benefit reforms in normal times (continuous lines) and in a recession with binding ZLB (dashed lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state. The inflation and interest rates are annualized and expressed in percentage points.

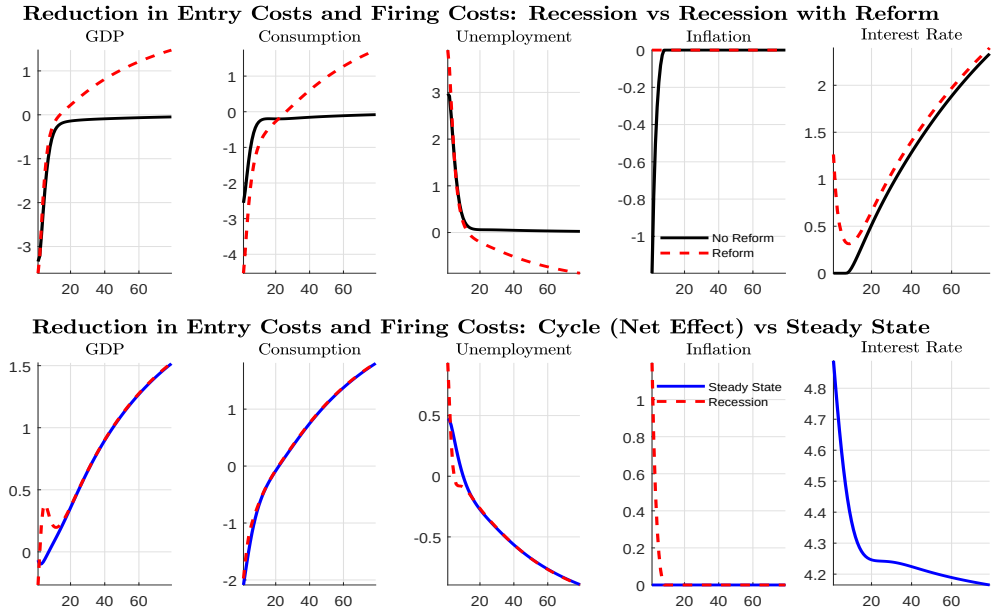

Figure A.5. *Top panel:* recession (continuous lines) versus recession followed by a reduction in barriers to entry and firing costs (dashed lines); *Bottom panel*: net effect of product market and firing cost reforms in normal times (continuous lines) and in a recession with binding ZLB (dashed lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state. The inflation and interest rates are annualized and expressed in percentage points.

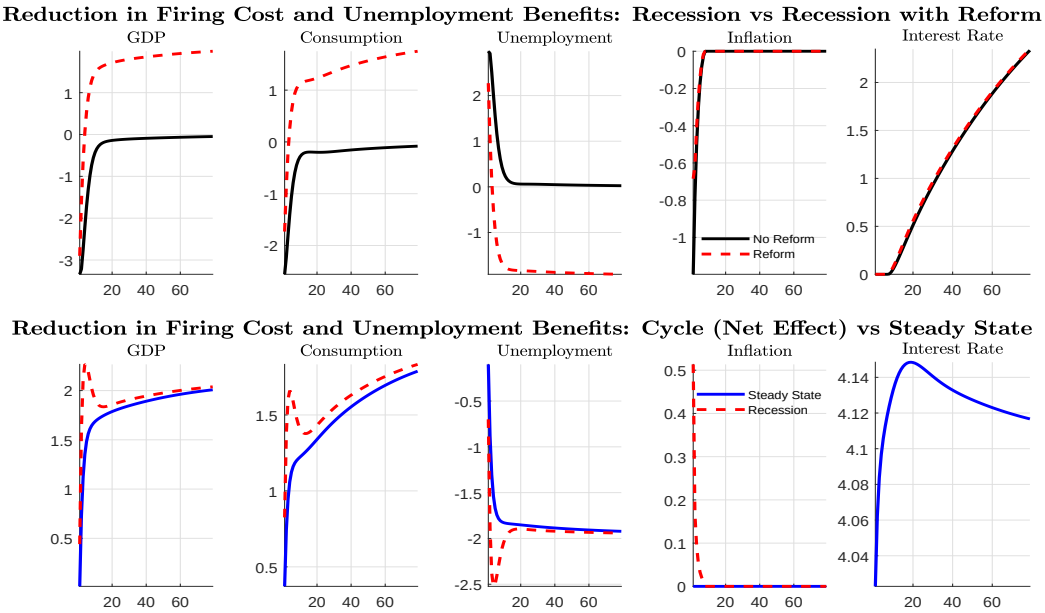

Figure A.6. *Top panel:* recession (continuous lines) versus recession followed by a reduction in unemployment benefits and firing costs (dashed lines); *Bottom panel*: net effect of unemployment benefit and firing cost reforms in normal times (continuous lines) and in a recession with binding ZLB (dashed lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state. The inflation and interest rates are annualized and expressed in percentage points.

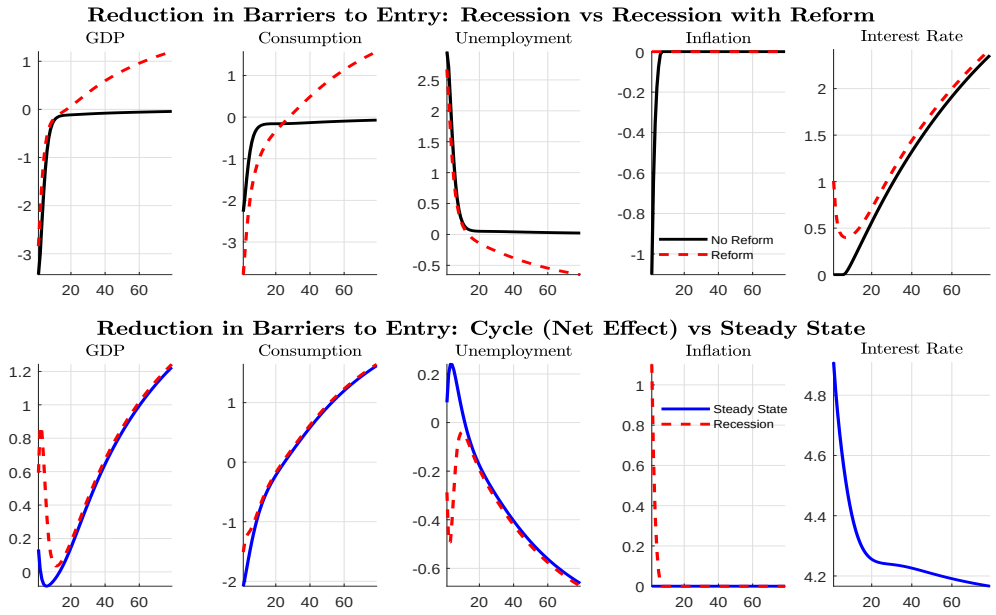

Figure A.7, two-sector model. *Top panel*: recession (continuous lines) versus recession followed by product market reform (dashed lines); *Bottom panel*: net effect of product market reform in normal times (continuous lines) and in a recession with binding ZLB (dashed lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state. The inflation and interest rates are annualized and expressed in percentage points.

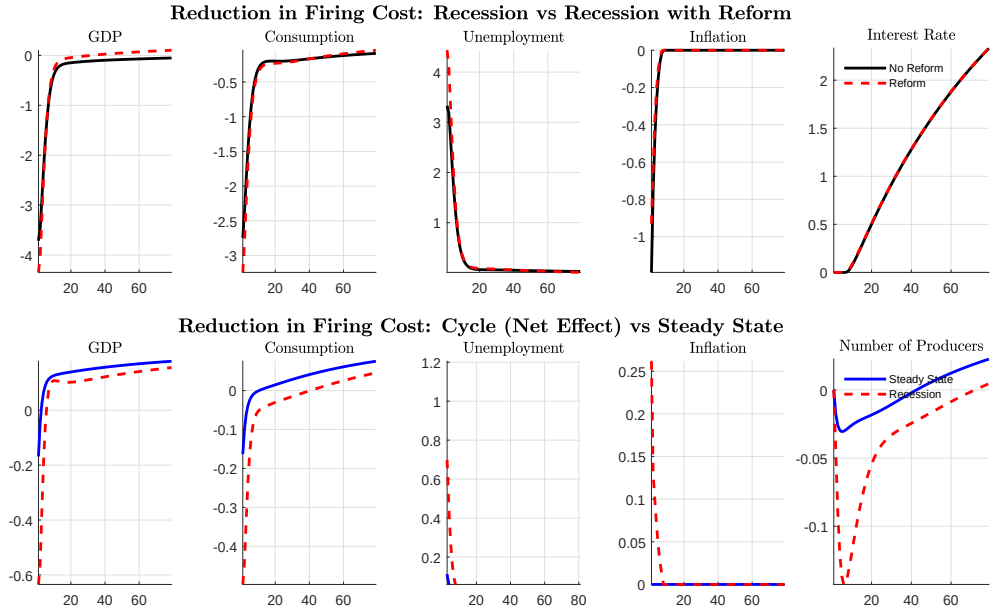

Figure A.8, two-sector model. *Top panel*: recession (continuous lines) versus recession followed by firing cost reform (dashed lines); *Bottom panel:* net effect of firing cost reform in normal times (continuous lines) and in a recession with binding ZLB (dashed lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state. The inflation and interest rates are annualized and expressed in percentage points.

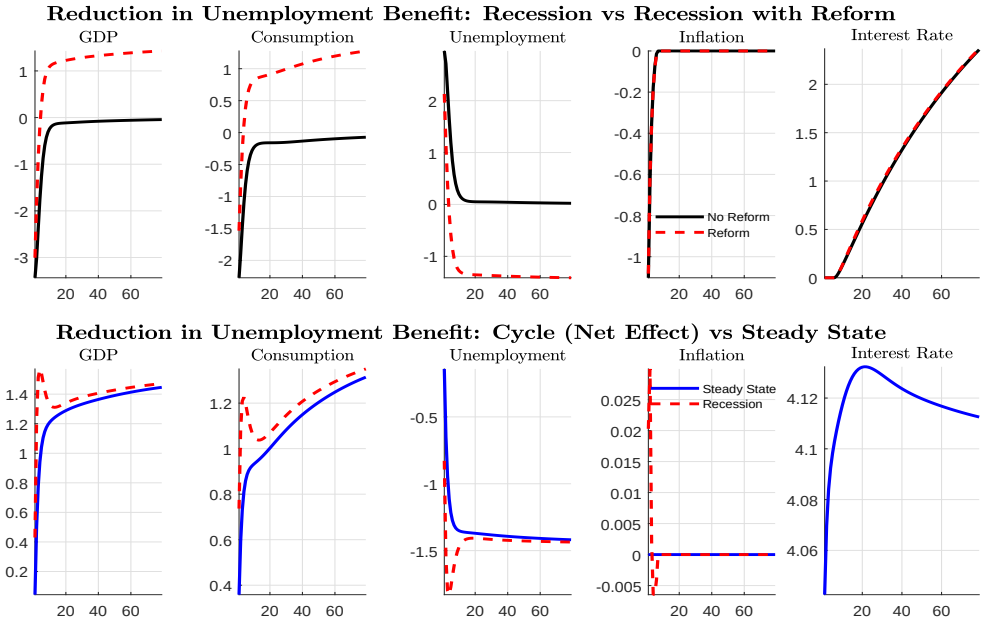

Figure A.9, two-sector model. *Top panel:* recession (continuous lines) versus recession followed by unemployment benefit reform (dashed lines); *Bottom panel*: net effect of unemployment benefit reform in normal times (continuous lines) and in a recession with binding ZLB (dashed lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state. The inflation and interest rates are annualized and expressed in percentage points.

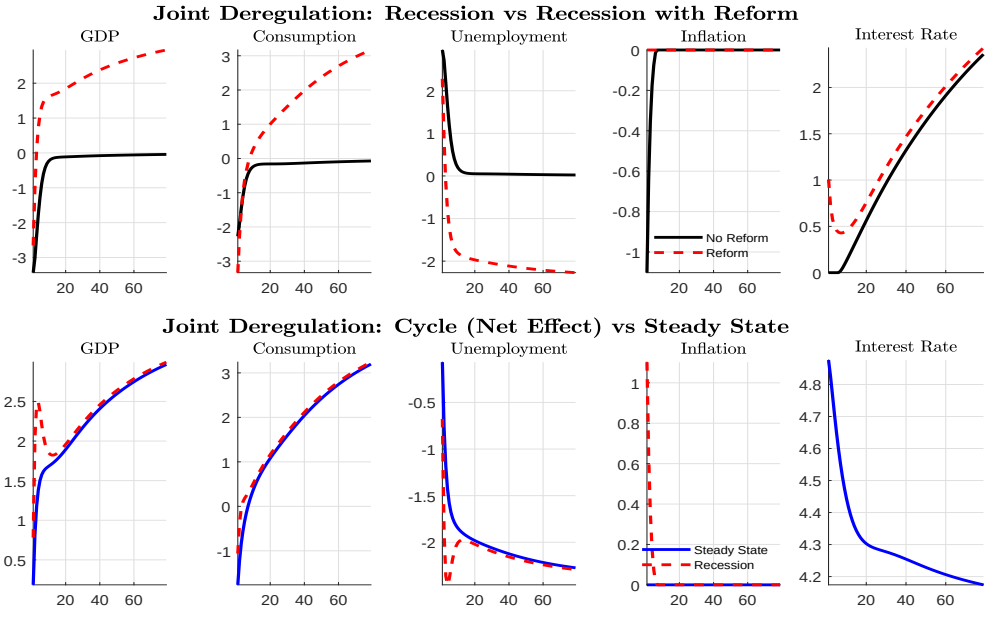

Figure A.10, two-sector model. *Top panel:* recession (continuous lines) versus recession followed by joint product and labor market reform (dashed lines); *Bottom panel*: net effect of joint product and labor market reform in normal times (continuous lines) and in a recession with binding ZLB (dashed lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state. The inflation and interest rates are annualized and expressed in percentage points.