

# Technical Appendix for “Market Reforms at the Zero Lower Bound”

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August 3, 2017

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## A Wage Determination

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

$$\eta\Delta_t^F(z) = (1 - \eta)\Delta_t^W(z), \quad (1)$$

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

$$\Delta_t^W(z) = w_t(z) - \varpi_t + E_t\tilde{\beta}_{t,t+1} (1 - G(z_{t+1}^c)) \tilde{\Delta}_{t+1}^W, \quad (2)$$

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

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

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

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

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):

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

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

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

$$\alpha\varphi_{\omega t} Z_t z k_{\omega t}^{\alpha-1}(z) = r_t^K. \quad (3)$$

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

$$\tilde{k}_{\omega t} = \left( \frac{r_t^K}{\alpha\varphi_{\omega t} Z_t} \right)^{\frac{1}{\alpha-1}} \tilde{z}_{\omega t}^{\frac{1}{1-\alpha}}, \quad (4)$$

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:

$$\frac{\kappa}{q_t} = E_t \left\{ \tilde{\beta}_{t,t+1} \left[ (1 - G(z_{\omega t+1}^c)) \psi_{\omega t+1} - G(z_{\omega t+1}^c) F_{t+1} \right] \right\}, \quad (5)$$

$$\psi_{\omega t} = \varphi_{\omega t} \frac{y_{\omega t}}{l_{\omega t}} - \tilde{w}_{\omega t} - r_t^K \tilde{k}_{\omega t} + \frac{\kappa}{q_t}, \quad (6)$$

By combining equations (??) and (??), we obtain

$$k_{\omega t}(z) = \tilde{k}_{\omega t} \left( \frac{z}{\tilde{z}_{\omega t}} \right)^{\frac{1}{1-\alpha}}. \quad (7)$$

Using equations (??), (??), and (??),  $J_t(z)$  can then be written as

$$J_t(z) = \pi_t(z) - w_t(z) + \frac{k}{q_t}. \quad (8)$$

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

$$\Delta_t^F(z) = \pi_t(z) - w_t(z) + \frac{k}{q_t} + F_t. \quad (9)$$

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

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

Using equation (??), we obtain:

$$\Delta_t^W(z) = w_t(z) - \varpi_t + \frac{\eta}{1 - \eta} \left[ \frac{\kappa}{q_t} + E_t \left( \tilde{\beta}_{t,t+1} F_{t+1} \right) \right]. \quad (10)$$

Inserting equations (??) and (??) into the sharing rule (??), 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

$$\tilde{w}_t = \eta \left\{ \tilde{\pi}_t + F_t - (1 - \lambda) E_t \beta_{t,t+1} F_{t+1} \right\} + (1 - \eta) \varpi_t. \quad (11)$$

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:

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

## B Market Regulation

### 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.<sup>1</sup> 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.

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<sup>1</sup>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.

## C Data-Consistent Variables

First, recall that the welfare-based price indexes imply:

$$P_t = \left[ (1 - \alpha_N) (P_t^T)^{1-\phi_N} + \alpha_N (P_t^N)^{1-\phi_N} \right]^{\frac{1}{1-\phi_N}},$$

$$P_t^T = \left[ (1 - \alpha_X) (P_{D,t}^T)^{1-\phi_T} + \alpha_X (P_{X,t}^{T*})^{1-\phi_T} \right]^{\frac{1}{1-\phi_T}}.$$

Next, define the variety effect as

$$\Delta_t^N \equiv \exp \left\{ \frac{\tilde{N} - N_t}{2\sigma \tilde{N} N_t} \right\}.$$

Therefore

$$P_t^N = \Delta_t^N \tilde{P}_t^N,$$

$$P_{D,t}^T = (\Delta_t^N)^{\xi-1} \tilde{P}_{D,t}^T,$$

$$P_{X,t}^{T*} = (\Delta_t^{N*})^{\xi-1} \tilde{P}_{X,t}^{T*}.$$

Therefore

$$P_t = \left[ (1 - \alpha_N) (P_t^T)^{1-\phi_N} + \alpha_N (\Delta_t^N \tilde{P}_t^N)^{1-\phi_N} \right]^{\frac{1}{1-\phi_N}}$$

and

$$P_t^T = \left[ (1 - \alpha_X) \left[ (\Delta_t^N)^{\xi-1} \tilde{P}_{D,t}^T \right]^{1-\phi_T} + \alpha_X \left[ (\Delta_t^{N*})^{\xi-1} \tilde{P}_{X,t}^{T*} \right]^{1-\phi_T} \right]^{\frac{1}{1-\phi_T}}.$$

By combining the above results, we obtain:

$$P_t^{1-\phi_N} = (1 - \alpha_N) \left[ (1 - \alpha_X) \left( (\Delta_t^N)^{\xi-1} \tilde{P}_{D,t}^T \right)^{1-\phi_T} + \alpha_X \left( (\Delta_t^{N*})^{\xi-1} \tilde{P}_{X,t}^{T*} \right)^{1-\phi_T} \right]^{\frac{1-\phi_N}{1-\phi_T}} + \alpha_N (\Delta_t^N \tilde{P}_t^N)^{1-\phi_N}.$$

The deflator is then given by

$$\Omega_t \equiv (1 - \alpha_N) \left\{ (1 - \alpha_X) \left[ (\Delta_t^N)^{\xi-1} \right]^{1-\phi_T} + \alpha_X \left( (\Delta_t^{N*})^{\xi-1} \right)^{1-\phi_T} \right\}^{\frac{1-\phi_N}{1-\phi_T}} + \alpha_N (\Delta_t^N)^{1-\phi_N}.$$

As discussed in the main text, we construct an average price index as

$$\tilde{P}_t = \Omega_t^{\frac{1}{\phi_N-1}} P_t.$$

In turn, given any variable  $X_t$  in units of consumption, its data-consistent counterpart is:

$$X_{R,t} \equiv \frac{P_t X_t}{\tilde{P}_t} = X_t \Omega_t^{\frac{1}{(1-\phi_N)}}.$$

## D Impulse Responses for the Foreign Economy

See Figures A.1-A.5. In the Foreign economy, GDP and employment temporarily fall relative to the initial steady state, since there are fewer resources available for domestic production as Foreign households invest in the Home economy. Once the number of producing firms in the deregulating economy has increased, the reduction in red-tape implies that more resources can be devoted to consumption and investment in physical capital. In addition, as jobs are reallocated to new entrants, unemployment falls, further boosting aggregate demand at Home and abroad. The larger number of available goods results in higher goods substitutability and lower markups.

## E Impulse Responses for a Reduction in Home Production

See Figure A.6.

## F Symmetric Reforms

See Figures A.7-A.10.

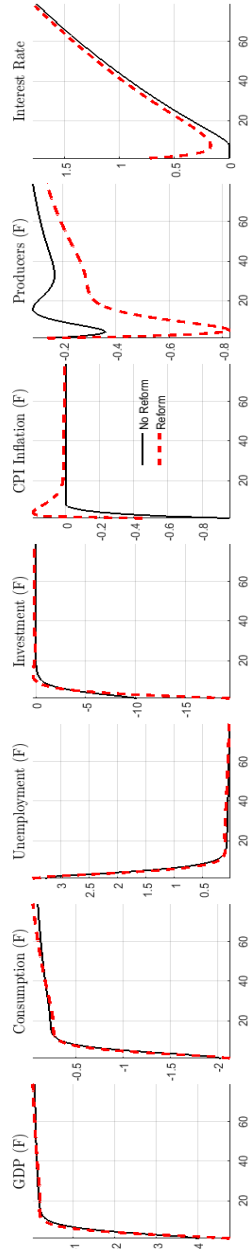
## References

- [1] Djankov, S., R. L. Porta, F. Lopez-De-Silanes, and A. Shleifer (2002): “The Regulation Of Entry,” *The Quarterly Journal of Economics*, 117: 1–37.
- [2] Koske, I., I. Wanner, R. Bitetti, and O. Barbiero (2014): “The 2013 Update of the OECD Product Market Regulation Indicators: Policy Insights for OECD and non-OECD Countries,” OECD Economics Department Working Papers.
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- [4] Mortensen, D. T., and C. A. Pissarides (2002): “Taxes, Subsidies and Equilibrium Labor Market Outcomes,” CEP DP 0519.
- [5] Pissarides, C. A. (2003): “Company Startup Costs and Employment,” in Aghion, P., R. Frydman, J. Stiglitz, and M. Woodford, eds., *Knowledge, Information, and Expectations in Modern Macroeconomics: In Honor of Edmund S. Phelps*, Princeton University Press, Princeton, NJ, pp. 479-504.

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

Reduction in Barriers to Entry: Recession vs Recession with Reform



Reduction in Barriers to Entry: Cycle (Net Effect) vs Steady State

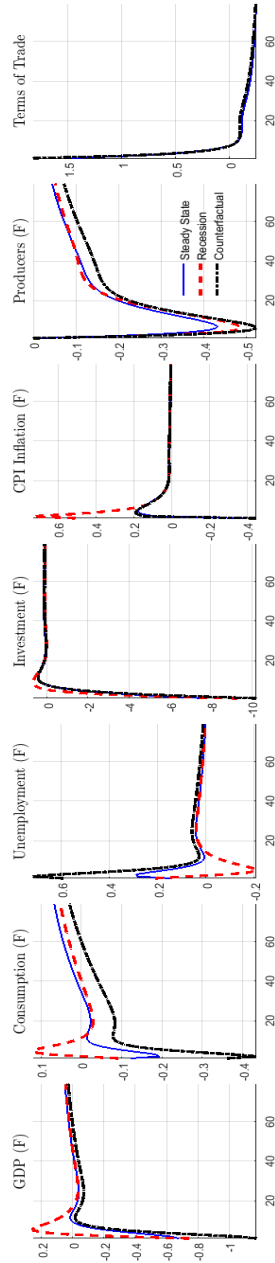
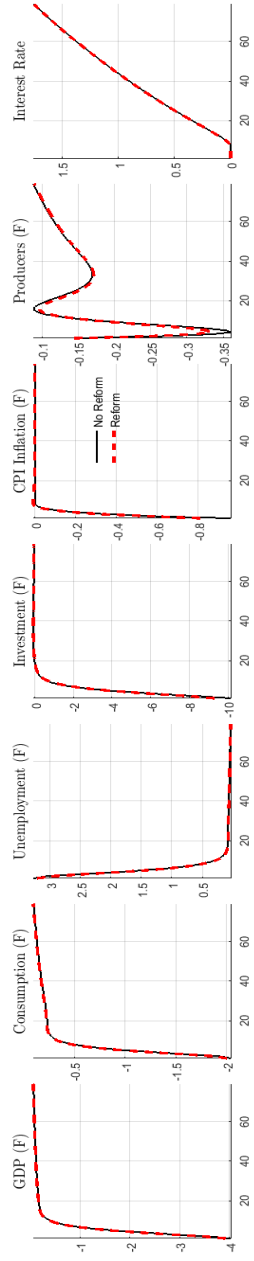


Figure A1. Foreign dynamics following Home product market reform. *Top panel*: recession (continuous lines) versus recession followed by Home product market reform (dashed lines); *Bottom panel*: net effect of Home product market reform in normal times (continuous lines), in a recession with binding ZLB (dashed lines), and in a recession where the interest rate is allowed to violate the ZLB (dotted lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state.



Reduction in Firing Cost: Recession vs Recession with Reform



Reduction in Firing Cost: Cycle (Net Effect) vs Steady State

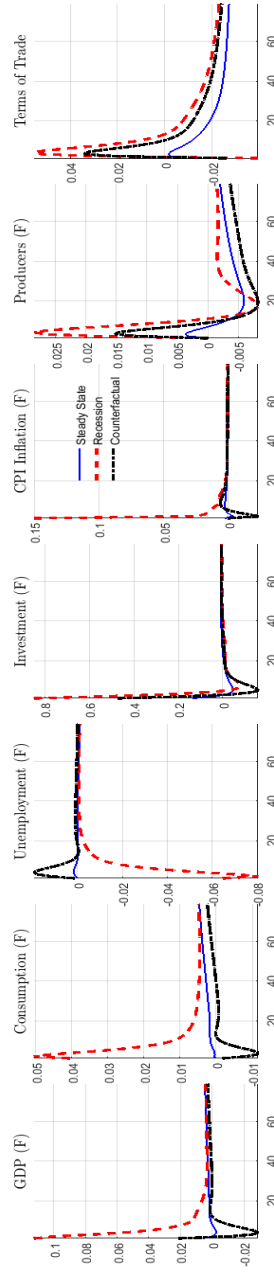
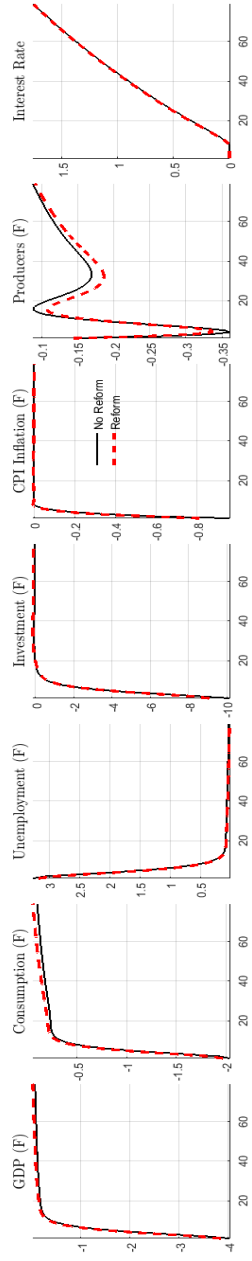


Figure A.2. Foreign dynamics following Home firing cost reform. *Top panel:* recession (continuous lines) versus recession followed by Home firing cost reform (dashed lines); *Bottom panel:* net effect of Home firing cost reform in normal times (continuous lines), in a recession with binding ZLB (dashed lines), and in a recession where the interest rate is allowed to violate the ZLB (dotted lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state.

Reduction in Unemployment Benefit: Recession vs Recession with Reform



Reduction in Unemployment Benefit: Cycle (Net Effect) vs Steady State

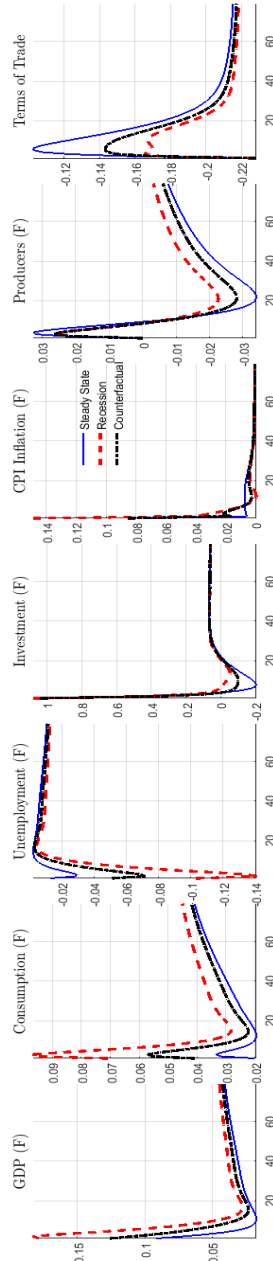


Figure A.3. Foreign dynamics following Home unemployment benefit reform. *Top panel:* recession (continuous lines) versus recession followed by Home unemployment benefit reform (dashed lines); *Bottom panel:* net effect of Home unemployment benefit reform in normal times (continuous lines), in a recession with binding ZLB (dashed lines), and in a recession where the interest rate is allowed to violate the ZLB (dotted lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state.

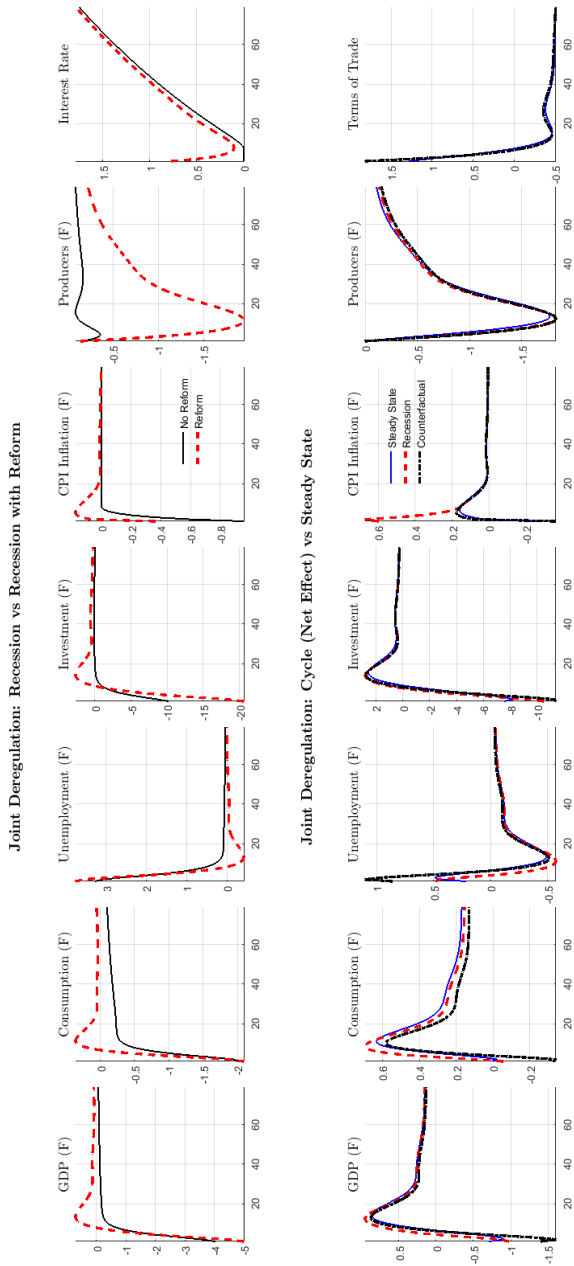


Figure A.4. Foreign dynamics following Home joint reform in product and labor market. *Top panel:* recession (continuous lines) versus recession followed by Home joint product and labor market reform (dashed lines); *Bottom panel:* net effect of Home joint product and labor market reform in normal times (continuous lines), in a recession with binding ZLB (dashed lines), and in a recession where the interest rate is allowed to violate the ZLB (dotted lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state.

Productivity Effects of Market Reforms

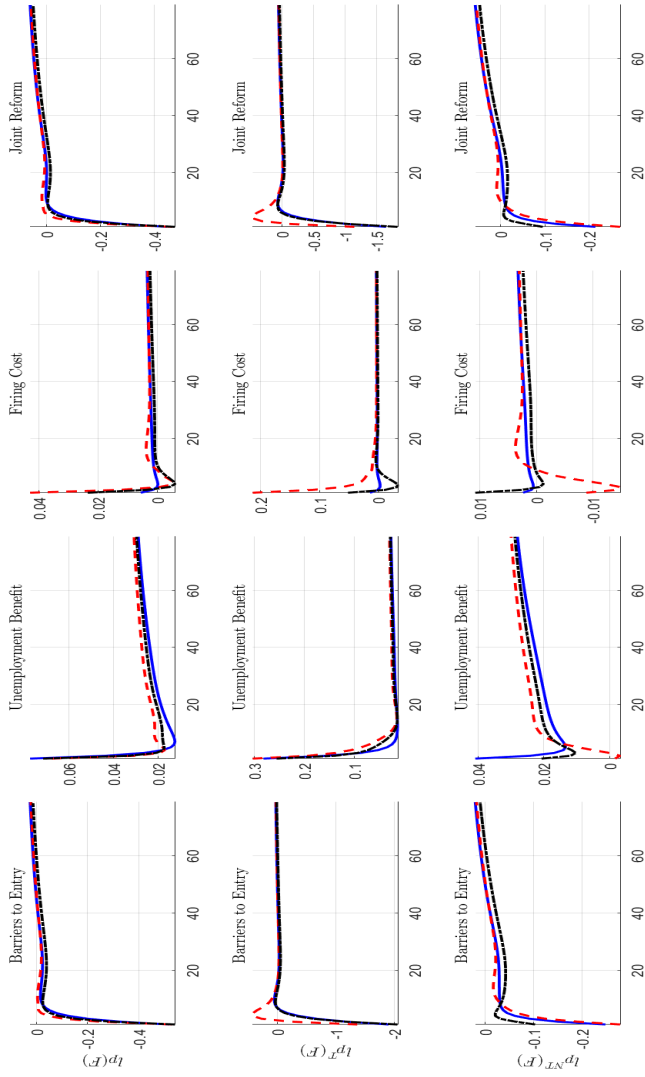
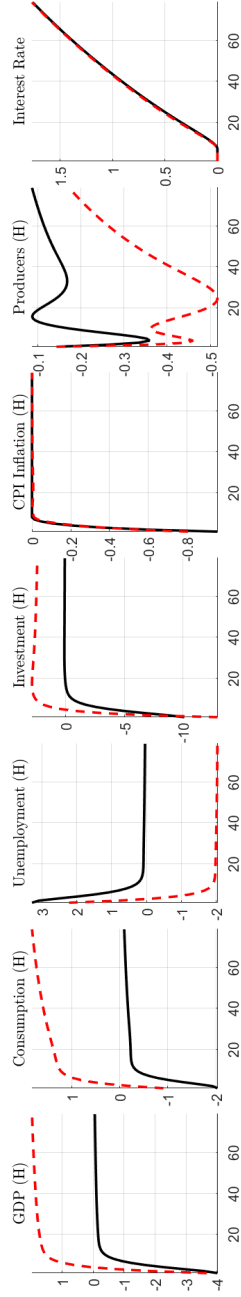


Figure A.5. Aggregate and sectoral labor-productivity dynamics in Foreign following Home market reforms in normal times (continuous lines), in a recession with binding ZLB (dashed lines), and in a recession where the interest rate is allowed to violate the ZLB (dotted lines). *First row*: aggregate labor productivity ( $lp_t^*$ ); *Second row*: labor productivity in the tradable sector ( $lp_t^{T*}$ ); *Third row*: labor productivity in the non-tradable sector ( $lp_t^{NT*}$ ).

**Reduction in Home Production: Recession vs Recession with Reform**



**Reduction in Home Production: Cycle (Net Effect) vs Steady State**

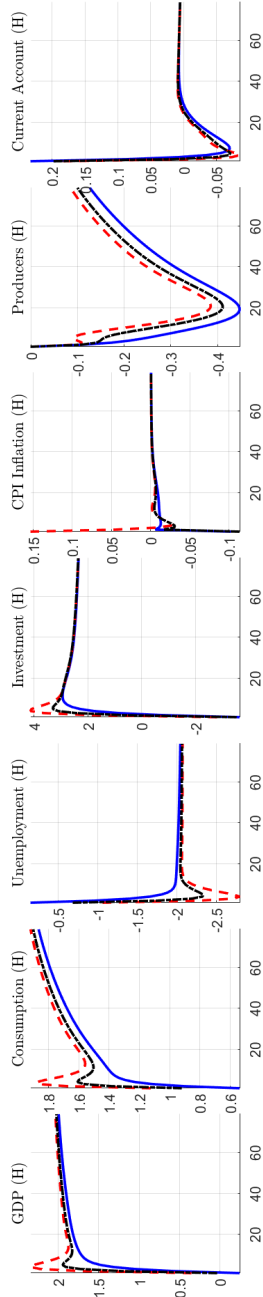
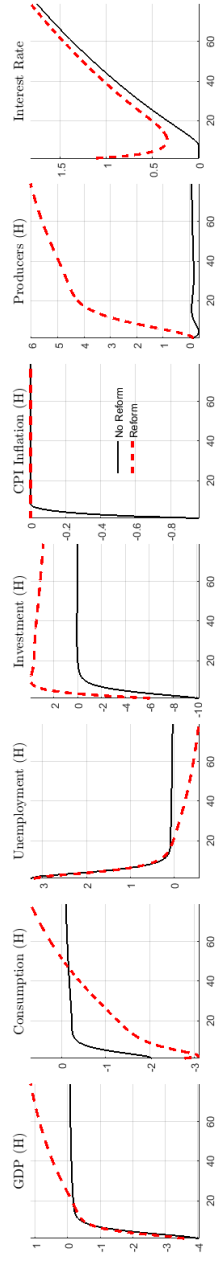


Figure A.6. *Top panel:* recession (continuous lines) versus recession followed by a reduction in home production (dashed lines); *Bottom panel:* net effect of a reduction in home production in normal times (continuous lines), in a recession with binding ZLB (dashed lines), and in a recession where the interest rate is allowed to violate the ZLB (dotted lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state.

Reduction in Barriers to Entry: Recession vs Recession with Reform



Reduction in Barriers to Entry: Cycle (Net Effect) vs Steady State

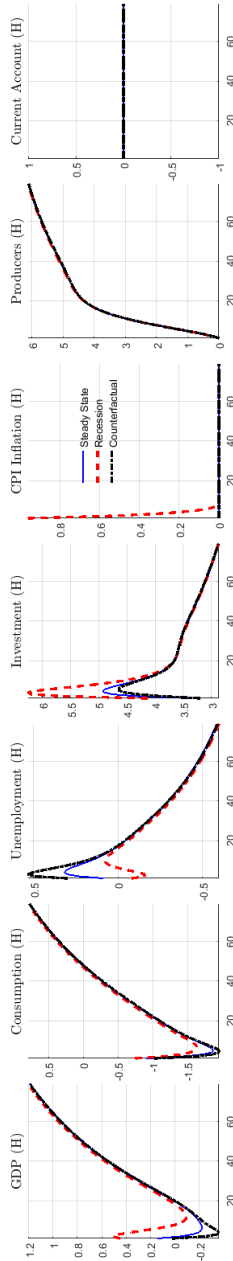
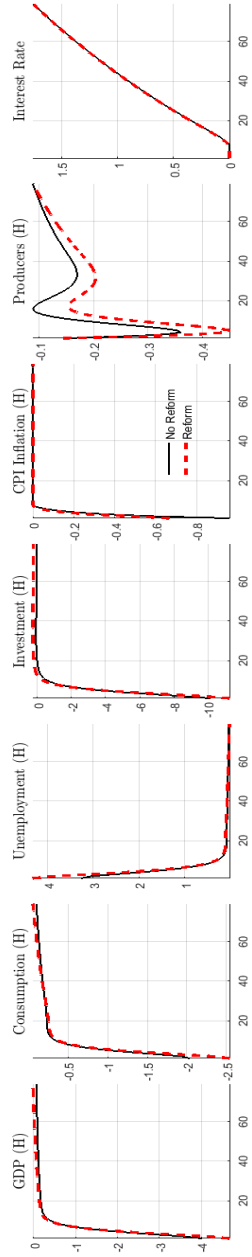


Figure A.7. *Top panel:* recession (continuous lines) versus recession followed by symmetric product market reform (dashed lines); *Bottom panel:* net effect of symmetric product market reform in normal times (continuous lines), in a recession with binding ZLB (dashed lines), and in a recession where the interest rate is allowed to violate the ZLB (dotted lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state.

Reduction in Firing Cost: Recession vs Recession with Reform



Reduction in Firing Cost: Cycle (Net Effect) vs Steady State

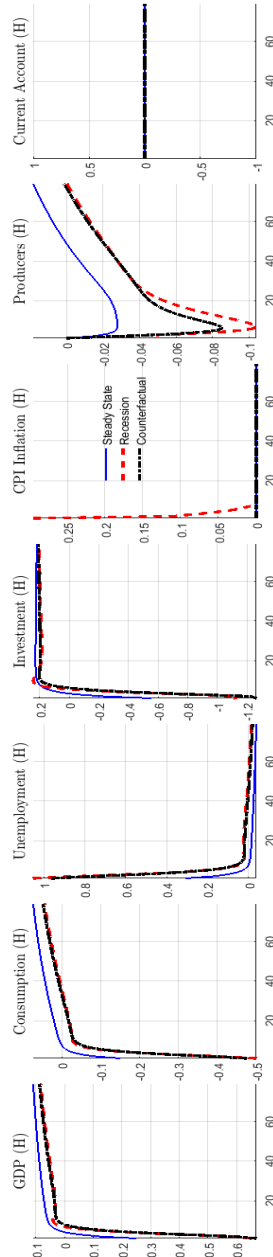
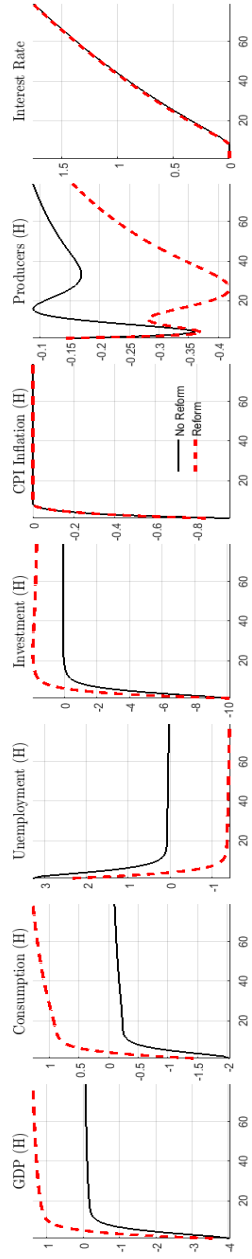


Figure A.8. *Top panel:* recession (continuous lines) versus recession followed by symmetric firing cost reform (dashed lines); *Bottom panel:* net effect of firing cost reform in normal times (continuous lines), in a recession with binding ZLB (dashed lines), and in a recession where the interest rate is allowed to violate the ZLB (dotted lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state.

Reduction in Unemployment Benefit: Recession vs Recession with Reform



Reduction in Unemployment Benefit: Cycle (Net Effect) vs Steady State

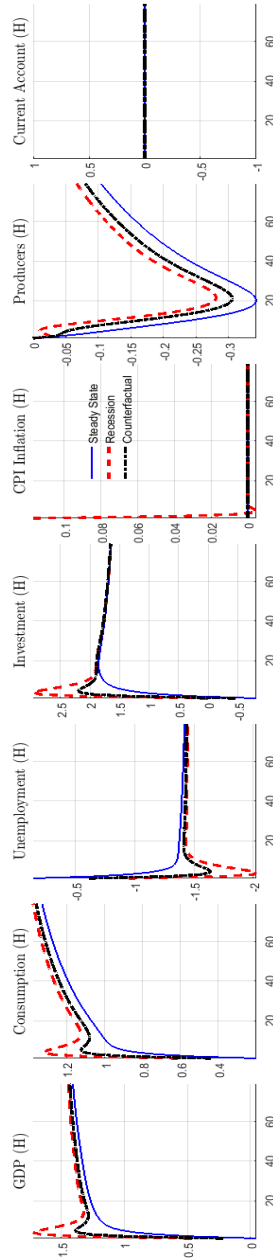
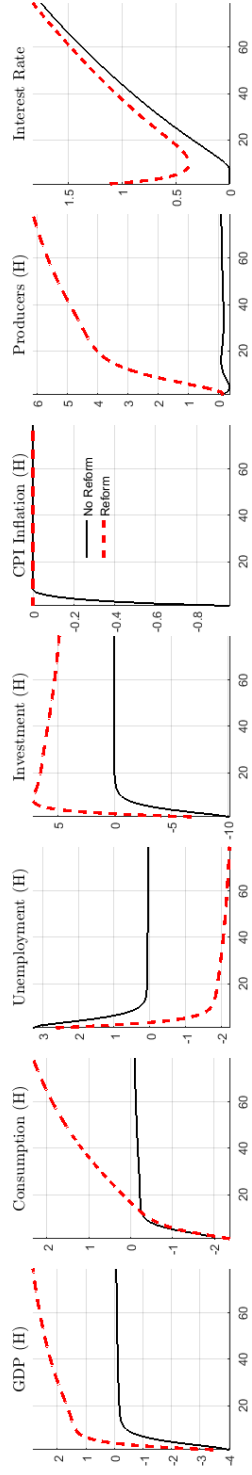


Figure A.9. *Top panel*: recession (continuous lines) versus recession followed by symmetric unemployment benefit reform (dashed lines); *Bottom panel*: net effect of unemployment benefit reform in normal times (continuous lines), in a recession with binding ZLB (dashed lines), and in a recession where the interest rate is allowed to violate the ZLB (dotted lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state.



Joint Deregulation: Recession vs Recession with Reform



Joint Deregulation: Cycle (Net Effect) vs Steady State

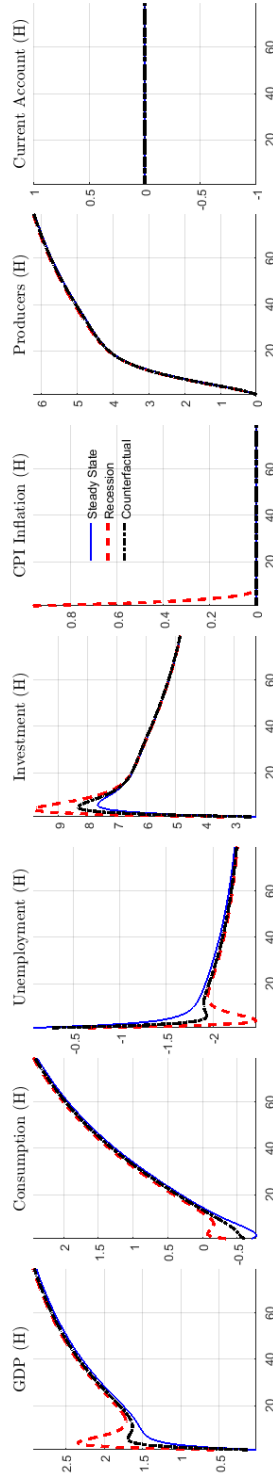


Figure A.10. *Top panel:* recession (continuous lines) versus recession followed by symmetric joint product and labor market reform (dashed lines); *Bottom panel:* net effect of joint product and labor market reform in normal times (continuous lines), in a recession with binding ZLB (dashed lines), and in a recession where the interest rate is allowed to violate the ZLB (dotted lines). Responses show percentage deviations from the initial steady state. Unemployment is in deviations from the initial steady state.