Capital Flows, Structural Change, and Productivity Growth

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Background

- Main idea: This paper studies how capital account restrictions and reserves policy can aid productivity growth through shaping composition of trade.
- Application: Can help explain "premature de-industrialization" and "industrial polarization" in recent lit. (Rodrick 2016; Sposi, Yi & Zhang 2024).
- Deindustrialization: Peak manufacturing share hump is 3.4 pp. lower post-1990. "Countries increasingly graduate from agriculture to services directly, bypassing industrialization." (Sposi et al.)
- Polarization: Cross-country variance of manufac. shares doubled post-1990, from 0.05 to 0.11.

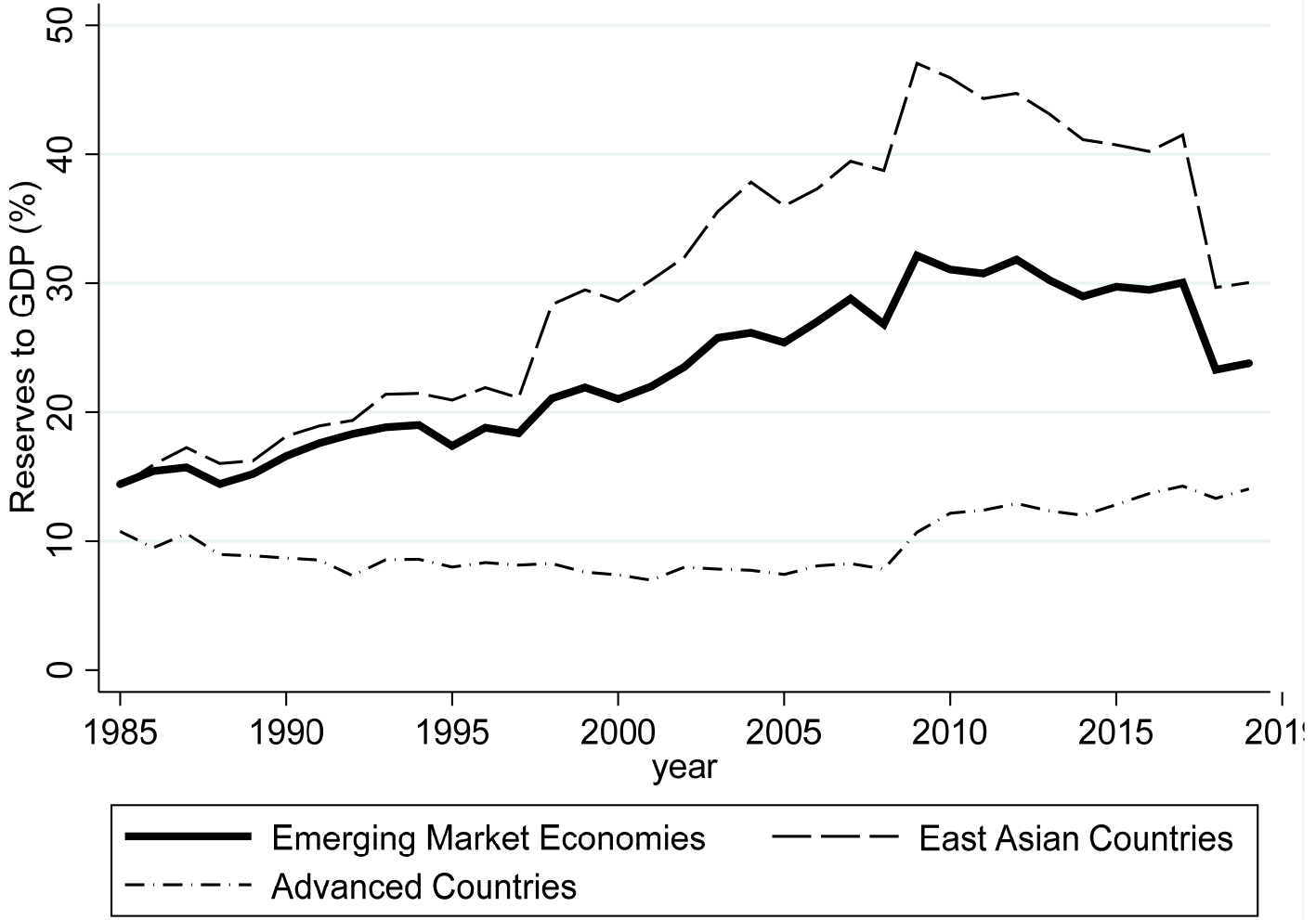
Background

- Sposi et al.: *"Accounting for this increased industry dispersion in the post-1990 period is the contrasting experiences across countries. Latin American countries (e.g. Brazil and Mexico) have much lower manufacturing value added shares than Asian economies (e.g. South Korea and Taiwan)…"*
- They explain in terms of sector-biased productivity growth and trade integration.
- We suggest differences capital account and exchange rate policy contributed to endogenous sector-biased productivity growth and polarization.

Background

- There is a large literature studying how currency undervaluation (China) can promote learning-by -doing through trade surpluses.
- Ongoing interest in exchange rate policy as 'industrial policy:' Ottonello et al., (2024); and Benigno et al. (2022), Choi & Taylor (2022).
- Sustained currency undervaluations associated with polices of reserve accumulation coincided with period of long-run growth in Asian economies.
- Further reason to qualify advice from intertemporal macro models on benefits of capital mkt. openness to finance investment and smooth consumption.

Average reserves (% of GDP) by group



Source: Bergin et al. (2023)

Empirical contribution

- We find clearer link of policy to growth using reserve accumulation as explan. variable rather than usual real exchange rate undervaluation:
- BOP under cap controls implies direct linkage of reserve accumulation to trade surplus, regardless of particular exchange rate mechanism.
  - Avoids estimation of “equilibrium” exchange rate
  - Avoids decision of which price elasticity to use.
  - Exchange rate endogenous, affected by shocks.
- Find policy associated with changes in firm dynamics variables: extensive margin of trade, firm numbers, domestic sourcing of intermediates.

Theoretical Contribution

- Suggest alternative externality to usual learning-by-doing, focused on growth in 'industrial complex-ity' in production chains (Matsuyama, 2008).
- We use model of "firm delocation" from trade (Krugman 1980; Ossa 2011).
- Adding roundabout production implies productivity gains from "supply chain capture".
- Two-country model rather than usual SOE, to track impact of policy on manufacturing in other country.
- Find complementary mechanisms: delocation amplifies effects of standard Learning-by-doing.

Related Literature

- Export-led growth by undervaluation: Rodrik (2008), Dooley et al.(2004), Aizenman & Lee (2010), Korinek & Serven (2016), Choi & Taylor (2022), Benigno & Fornaro (2022)), Ottonello et al (2024).
  - ***We propose new mechanism based on firm dynamics***
- Literature on premature deindustrialization and industry polarization: Rodrik (2016), Huneeus and Rogerson (2020), Fujiwara and Matsuyama (2022), Sposi, Yi & Zhang (2023)
  - ***We propose may be policy induced***
- Macro firm literature exchange rate fluctuations too short-lived to affect ext. margins (Ruhl 2008), Ghironi and Melitz (2005).
  - ***Sustained undervaluation is possible with capital controls.***
- Large optimal capital control Literature:
  - ***Different externality; benefits from lower TOT/competitiveness***
- Debt overhang limits on growth: Aguiar and Amador (2011), Gourinchas & Jeanne (2013), Alfaro, Kalemli-Ozcan, Volosyvich (2014).

Plan of rest of presentation

- Empirical: Panel growth regressions linking capital account policy to firm dynamics variables.
- Describe theoretical model, combining macro elements to describe capital account policy and trade elements for firm delocation externality.
- Quantitative simulations of model.
- Theoretical extensions (time permitting)

Empirics

Data

- Sample: 45 countries (22 emerging and 23 advanced), 1985-2007 (ending before crisis).
- Use 5-year averages.
- Main regressors:
  - CC_{it}: capital control measure: Chinn and Ito (2008), inverted so [0,1], rising in closedness of capital account.
  - $\Delta RSRV_{it}$: annual change in reserves / GDP
  - $CC_{it} \times \Delta RSRV_{it}$: interaction term

Data Cont'd: variables of interest

- Sectoral Labor productivity: $LP^{S}_{j,t} = (\frac{VA^{S}_{it}}{PVA^{S}{}_{it}})/L^{S}{}_{it}$

  (authors' own construction from various data sources including KLEMS)

- Extensive (intensive) margins of trade: from Hummels and Klenow (2005)

- Number of incorporated firms: from Global Financial Development Database, World Bank

- Domestic intermediates share: total intermediates by industry from KLEMS for subset of 27 countries; imported intermediates from WITS, World Bank.

Labor Productivity Growth regression specification

$$\Delta \ln(LP_{it}) = \alpha_0 + \alpha_1 \ln\left(LP_{it,0}\right) + \alpha_2 CC_{it} + \alpha_3 \Delta RSRV_{it}$$
$$+\alpha_4 (CC_{it} \times \Delta RSRV_{it}) + X'_{it}\gamma + \eta_i + period_t + \varepsilon_{it},$$

1) Country and time fixed effects estimation.

2) System GMM estimation, Arellano and Bover (1995), Blundell and Bond (1998) with instrument (lag) for lagged dependent variable.

Table 1. Labor productivity growth

	(1)	(2)	(3)	(4)
Dependent variable	Manufacturing productivity growth		Non-Manufacturing productivity growth	
Methods	Panel within	System GMM	Panel within	System GMM
Initial productivity	-0.067***	0.0124	-0.0145	0.0117
	(0.0132)	(0.0078)	(0.0321)	(0.0136)
Capital controls (CC)	0.0068	-0.0061	0.0040	-0.0008
	(0.0145)	(0.0234)	(0.0126)	(0.0246)
d.Reserves/GDP	-0.4464**	-0.3574	-0.0824	0.0202
	(0.2054)	(0.2495)	(0.1899)	(0.2410)
Capital controls	1.816***	1.598***	-0.0179	0.0816
× d.Reserves/GDP	(0.301)	(0.501)	(0.489)	(0.620)

Significance: *, ** and *** are the significance level at 10%, 5% and 1%.
Clustered robust standard errors at country level

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Finding: Combination of reserve accumulation and capital controls has robust positive effect on productivity growth specific to manufacturing sector.

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Interpret estimates

- Significant effect in manufacturing sector but not in non-manufacturing sector.
- Column (1): for country with broadest capital controls, raising reserves ratio one ppt each year raises labor productivity growth over 5 yrs 1.37 ppt. (= 1.816 - 0.446).
- For median capital control value among emerging markets (CC = 0.525), result indicates 0.51 ppt labor productivity growth over 5 years.

Table 1b. Efforts to control for endogeneity of reserves

	(1)	(2)	(3)
Methods	Panel within	System GMM	System GMM
Sample	Full sample	Full sample	Emerging market
Endog. controls	Instrumented d.(Res/GDP)	Lagged values	
Endog. regressors	Initial productivity, TOT, Prv. credit/GDP	Initial productivity, TOT, Prv. credit/GDP, d.(Res./GDP), and d.(Res./GDP)×CC	
Initial productivity	0.0149*	0.0104	0.0063
	(0.0089)	(0.0079)	(0.0062)
Capital controls (CC)	-0.0101	0.0008	0.0102
	(0.0460)	(0.0231)	(0.0306)
d.Reserves/GDP	-0.855	-0.148	-0.446
	(1.040)	(0.402)	(0.535)
Capital controls	4.129*	1.632**	2.074***
***d.Reserves/GDP**	(2.498)	(0.677)	(0.766)

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Clustered robust standard errors at country level

Firm dynamics regressions specification

$$FD_{it}^{S} = \beta_0 + \beta_1 CC_{it} + \beta_2 \Delta RSRV_{it} + \beta_3 (CC_{it} \times \Delta RSRV_{it}) + H_{it}'\gamma + \eta_i + period_t + e_{it}$$

where FD_{it}^{S} indicates firm dynamics variables:
- extensive margins,
- # of listed domestic firms,
- domestic intermediate input shares.

Table 2. Firm Dynamics variables

Dependent variable	(1) manufac labor shares	(2) Extensive margins of exports	(3) Intensive margins of exports	(4) # of listed firms	(5) Domestic intermediate share
Capital controls	0.020***	0.005	-0.004	0.354*	0.214***
	(0.007)	(0.017)	(0.011)	(0.196)	(0.057)
d.Reserves/GDP	-0.237	-0.882***	-0.047	-5.008**	-0.077
	(0.147)	(0.292)	(0.152)	(2.254)	(0.670)
Capital controls	0.540**	2.437***	0.035	12.077*	2.849*
× d.Res/GDP	(0.246)	(0.646)	(0.269)	(7.136)	(1.535)
RGDP per capita	0.455***	0.612***	0.154*	-0.922	-0.644*
	(0.091)	(0.173)	(0.088)	(1.399)	(0.316)
(log) RGDP per capita squared	-0.026***	-0.033***	-0.008	0.076	0.031*
	(0.005)	(0.009)	(0.005)	(0.076)	(0.018)

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Finding: Capital account policy associated with rise in manufacturing labor share, firm creation, and use of domestic intermediates.

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Theoretical Model

Theoretical Model Summary

- Two countries; Two sectors: traded and nontraded
- Traded (manufacturing) sector: differentiated goods, monopolistic competition, firm entry, iceberg trade cost, possible learning-by-doing.
- Manufacturing uses composite of other final goods in production: roundabout production.
- Home government uses reserve accumulation and capital controls (fully closed) to set real exch. rate.
- No need sticky prices. Mon. policy chooses price.
- Track how undervaluation affects firm entry, manufacturing share, and labor productivity.

Goods market structure

Home consumption index, C, includes

- n varieties h of the differentiated good (D) produced in Home country,
- n^* varieties f produced in Foreign,
- Home nontraded (N).

where

$$C_t \equiv \left(\nu^{\frac{1}{\eta}} C_{T,t}^{\frac{\eta-1}{\eta}} + (1-\nu)^{\frac{1}{\eta}} C_{N,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}$$

$$C_{T,t} \equiv \left(\int_0^{n_t} c_t(h)^{\frac{\phi-1}{\phi}} \, dh + \int_0^{n_t^*} c_t(f)^{\frac{\phi-1}{\phi}} \, df \right)^{\frac{\phi}{\phi-1}}$$

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Households Problem

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\sigma} C_t^{1-\sigma}{}_t + \ln \frac{M_t}{P_t} - \frac{1}{1+\psi} l_t^{1+\psi} \right]$$

$$P_t C_t + \left(M_t - M_{t-1} \right) + \left(B_{Ht} - B_{Ht-1} \right) = W_t l_t + \Pi_t + i_{t-1} B_{Ht-1} - T_t$$

- Utility from consumption, real money balances (M/P); disutility from labor (l).
- Income from labor earnings at wage rate W, interest (i) on domestic bonds (B_H), profits from ownership of firms (Π). Pay lump sum tax (T).
- Precluded from holding foreign bonds.

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Household Problem Implies

Consumption Euler: $$\frac{1}{P_t C_t^{\sigma}} = \beta\left(1+i_t\right) E_t\left[\frac{1}{P_{t+1} C_{t+1}^{\sigma}}\right]$$

Labor supply: $$\frac{W_t}{P_t} = l_t{}^{\psi} C_t^{\sigma}$$

Money demand: $$\frac{M_t}{P_t} = C_t^{\sigma}\left(\frac{1+i_t}{i_t}\right)$$

Traded (Manufacturing) Goods

- Production uses labor and composite of other differentiated goods, with sector productivity shock, α_{Tt}

$$y_t(h) = \alpha_{T,t}\left[G_t(h)\right]^{\zeta}\left[l_t(h)\right]^{1-\zeta}$$

where $G_t(h)$ follows same demand as $c_t(h)$.

- No firm heterogeneity.
- prepay a one-time sunk entry cost, K_t, in units of combined labor and differentiated goods index.
- Face iceberg trade cost τ.
- No fixed trade cost; all manuf. goods are traded.

Firm Decisions

- Managers maximize firms' discounted value:

$$v_t(h) = E_t\left\{\sum_{s=0}^{\infty}\left(\beta(1-\delta)\right)^s \frac{\mu_{t+s}}{\mu_t}\pi_{t+s}(h)\right\}$$

Subject to exit shock, δ, where $\mu_t = P_t C_t^{\sigma}$

and profits are:

$$\pi_t(h) = p_t(h)d_t(h) + e_t p_t^*(h)d_t^*(h) - mc_t y_t(h)$$

$mc_t = \zeta^{-\zeta}(1-\zeta)^{\zeta-1} P_{D,t}{}^{\zeta} W_t^{1-\zeta} / \alpha_{D,t}$ is marginal cost.

and demand is $d_t(h) = c_t(h) + d_{G,t}(h) + d_{K,t}(h)$

Firm Decisions, cont.

- Optimal choice of inputs: $\frac{P_{T,t} G_t(h)}{W_t l_t(h)} = \frac{\zeta}{1-\zeta}$
- Firm price setting (flexible prices): in home currency units, where e is nominal exch rate.

$$p_t(h) = \frac{\phi}{\phi - 1} mc_t \qquad \text{at home}$$

$$p_t^*(h) = (1+\tau)\, p_t(h) / e_t \qquad \text{abroad}$$

- Firm entry until firm value equals entry cost:

$$v_t(h) = P_{Tt} K_t$$

- Firm number law of motion: $n_{t+1} = (1-\delta)(n_t + ne_t)$

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Non-traded Good Production

- Production linear in labor, subject to own shocks:

$$y_{N,t} = \alpha_N l_{N,t}$$

- Firms perfectly competitive, price takers:

$$p_{N,t} = W_t / \alpha_N$$

Government Policies

- Simplified version of model of Chinese policy from Chang, Liu and Spiegel (2015).
- Home gov't purchases foreign bonds as reserves R, sterilizes effect on M with taxes T.
- Gov't budget constraint:

$$T_t + \left(M_t - M_{t-1}\right) + \left(B^s_{H,t} - \left(1+i_{t-1}\right)B^s_{H,t-1}\right) = e_t\left(R_{F,t} - \left(1+i^*_{t-1}\right)R_{F,t-1}\right)$$

- Fixed money supply: $M_t = \overline{M}$
- Constant level of bond issuance, sold only domestically: $B^s_{H,t} = \overline{B^s_H}$

Government Policies, cont'd

- Home reserves policy rule: sets change in reserves each period as share of GDP:

$$e_t \left(R_{F,t} - R_{F,t-1} \right) \Big/ GDP_t = \Omega_t$$

- This determines exchange rate: Reserve accumulation implies depreciation, since capital controls prevent offsetting private asset trades.
- Since monetary policies set price levels, both real and nominal exch. rates determined above.

Balance of Payments

- Combining budget and resource constraints, (with zero private international asset trade):

$$\int_0^{n_t} e_t p_t^*(h) d_t^*(h) dh - \int_0^{n_t^*} p_t(f) d_t(f) df = e_t \left(R_{Ft} - \left(1 + i_{t-1}^*\right) R_{Ft-1} \right)$$

- Where left side is trade balance, and rights side is new government reserves purchases.

Summary of theoretical mechanism

- Reserve accumulation with capital controls implies trade surplus, raising demand for home tradeds.
- Induces rise in entry of home firms producing traded (manufacturing) good; fall in rest of world.
- Production delocation externality (Ossa 2011) from concentrating global manufac. in home: cost of traded goods falls due to savings on trade cost. Firms do not internalize this effect.
- In trade, this directly lowers CPI, raises welfare.
- In our model, larger market share of traded goods lowers price index of intermediate inputs, which raises labor productivity ("supply chain capture").

Benchmark Model Simulation

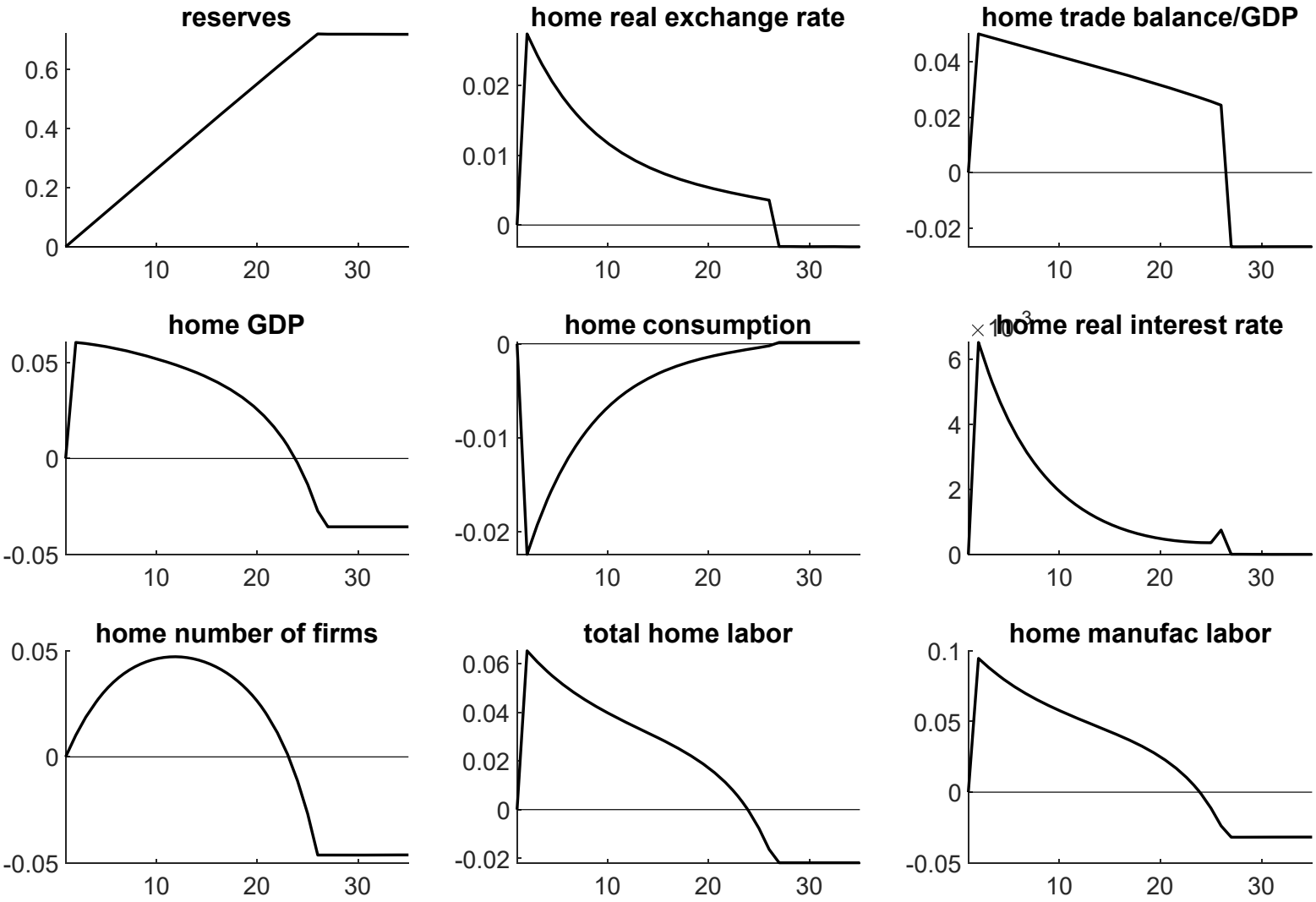
Illustrative Simulation Experiment:

- Start from symmetric steady state with 0 reserves, balanced trade, real exch. rate 1.0.
- Home country adopts policy of purchasing reserves annually by 5% of GDP for 25 years (China average 2006-2014).
- Policy surprise period 1, then perfect foresight.
- Assume private international asset trade precluded throughout experiment.
- Solve for equilibrium as nonlinear forward-looking deterministic system.

Parameter Values

Preferences	
Risk aversion	$\sigma = 2$
Time preference	$\beta = 0.96$
Labor supply elasticity	$1/\psi = 1.9$
Traded goods share	$\nu = 0.5$
Substitution elasticity between sectors	$\eta = 0.5$
Differentiated (traded) goods elasticity	$\phi = 5.2$
Technology	
Firm death rate	$\delta = 0.1$
Intermediate input share	$\varsigma = 0.55$
Trade cost	$\tau_D = 0.33$
Firm sunk entry cost	$\overline{K} = 1$
Productivities	$\alpha_T = \alpha_N = 1$
Policy	
Monetary policy	$\overline{M} = \overline{M^*} = 1$
Reserves	$\Omega_t = 0.05, t > 1$

Simulation for Benchmark Model:



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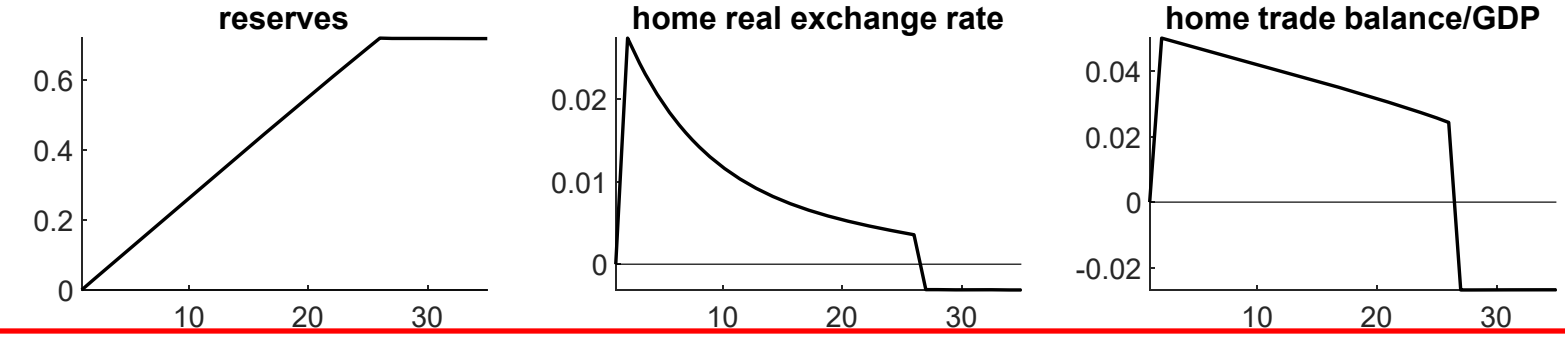
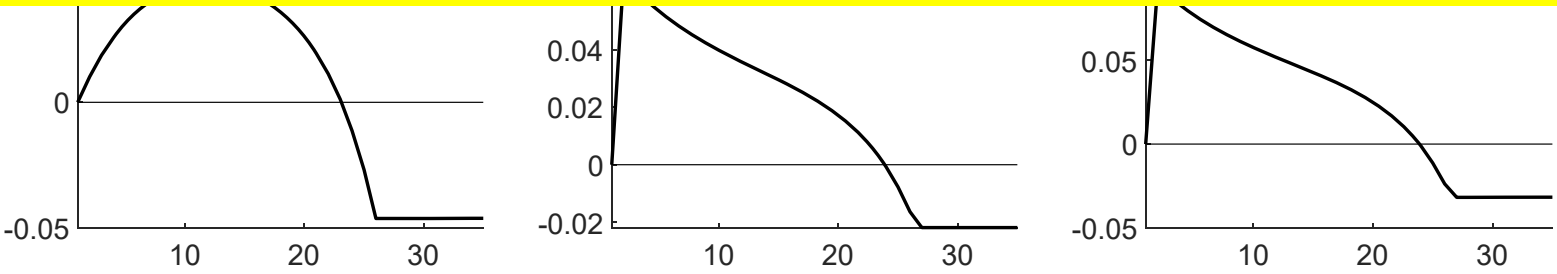
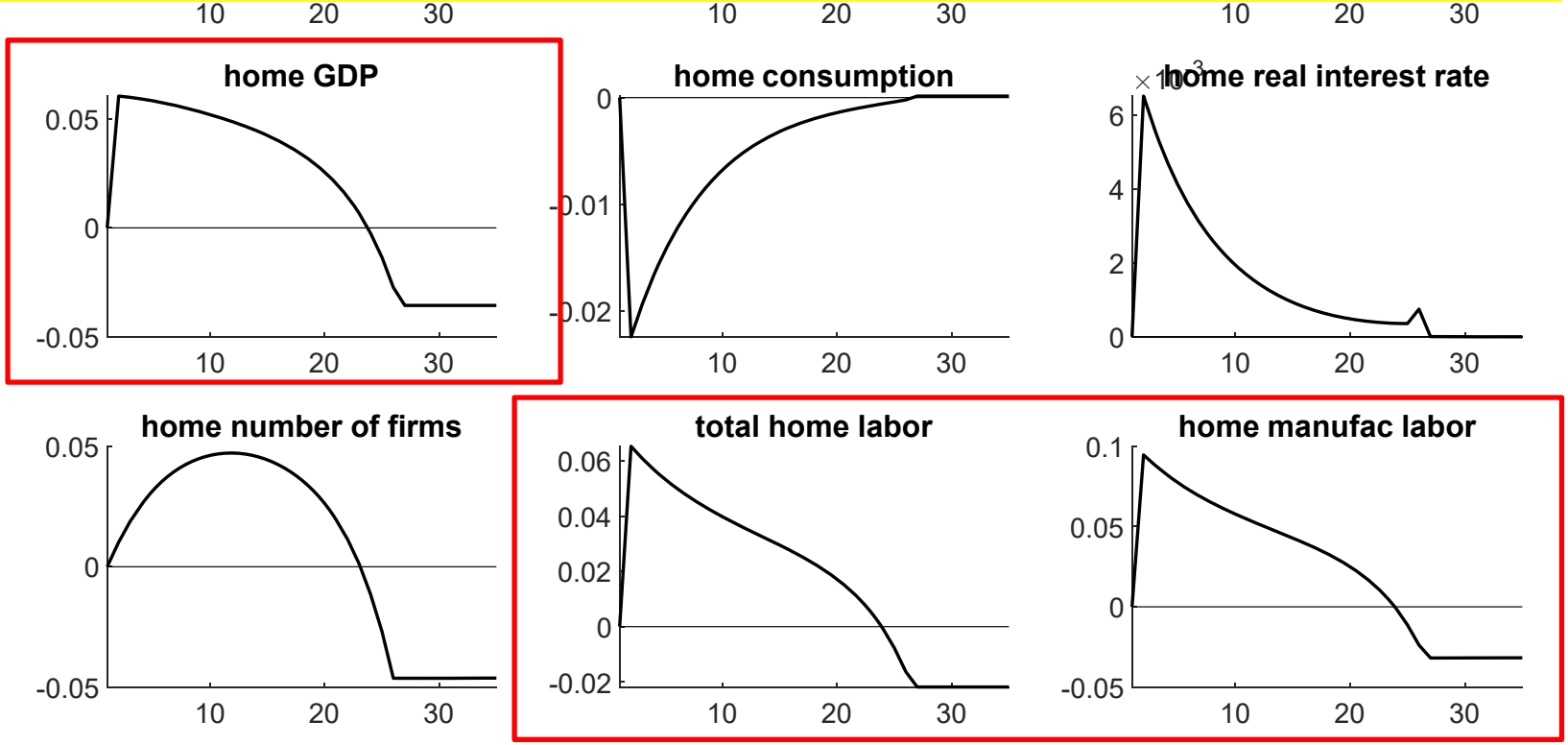


- Reserves purchase implies 3% real deprecation. (Appreciation over time partly due Balassa-Samuelson)
- Reserves purchases imply trade surplus. Deficit after policy ends, due to interest on NFA in new steady state



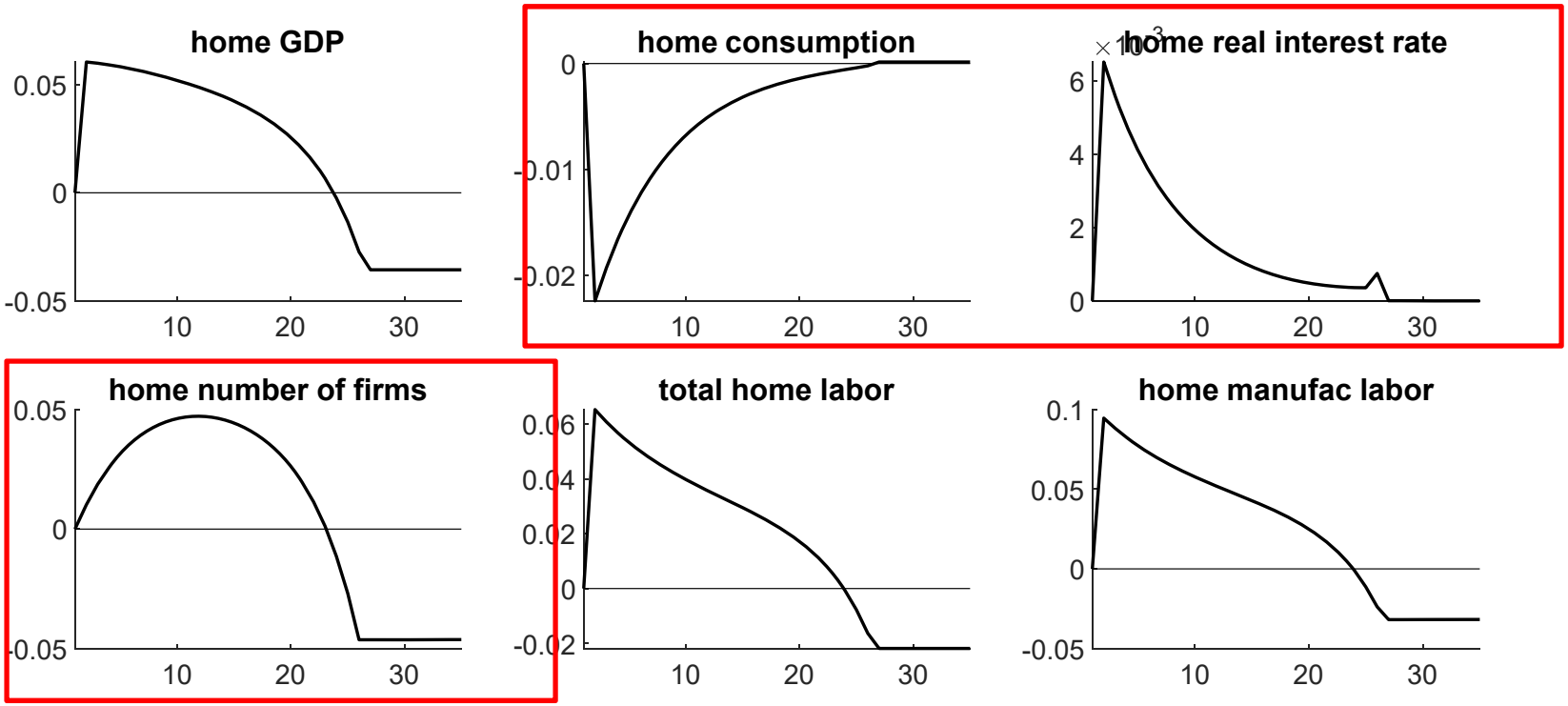
Simulation for Benchmark Model:

- Home GDP rises initially due to rise in home overall labor supply.
- Manufacturing labor rises more than proportionately.

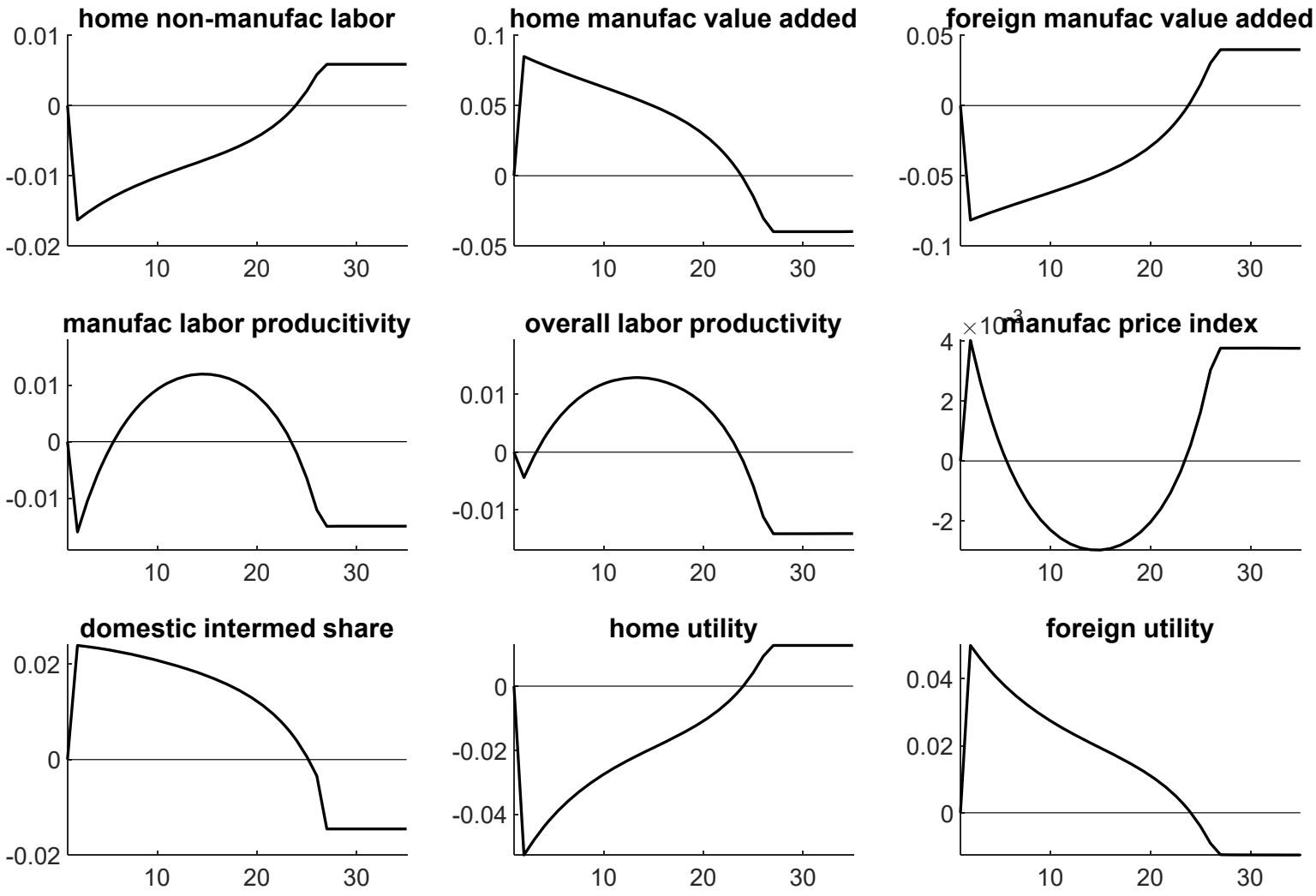


Simulation for Benchmark Model:

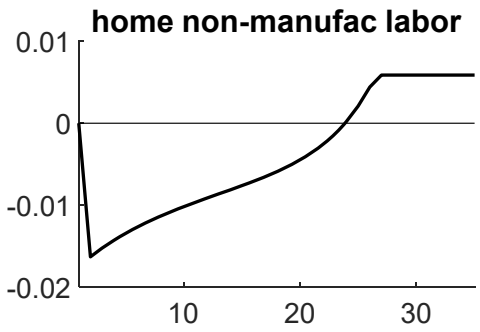
- Investment in new firm creation.
- Is gradual, since capital controls force this to be financed by domestic saving alone (high real int rate)
- Falls in anticipation of end of policy.

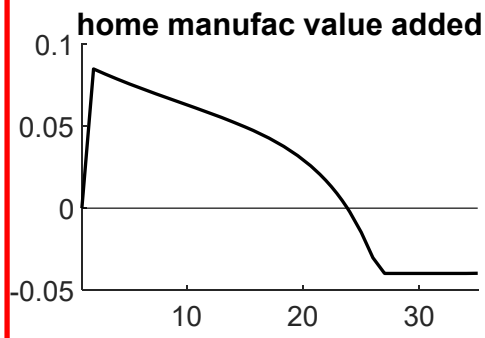


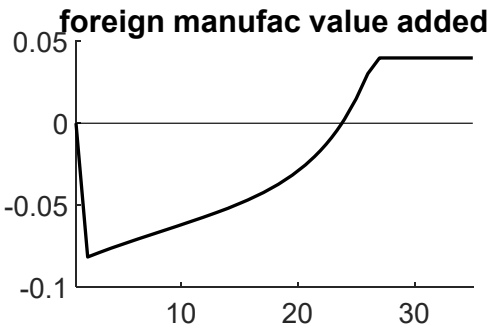
Simulation for Benchmark Model, cont.:



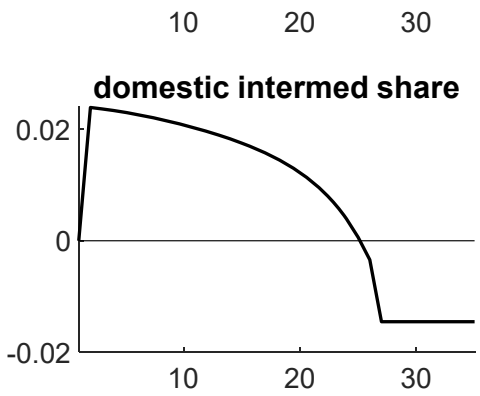
Simulation for Benchmark Model, cont.:

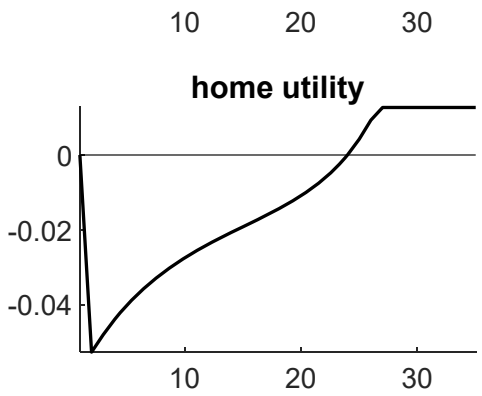


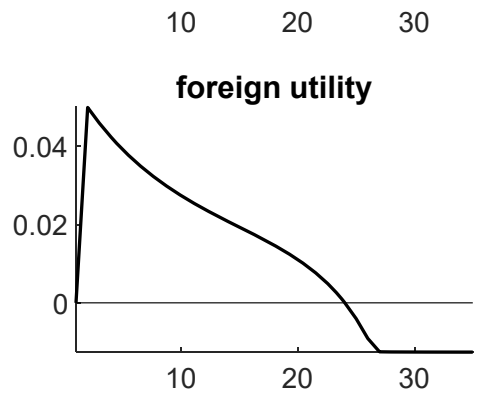




- Rise in home manufacturing during policy mirrored by fall abroad.

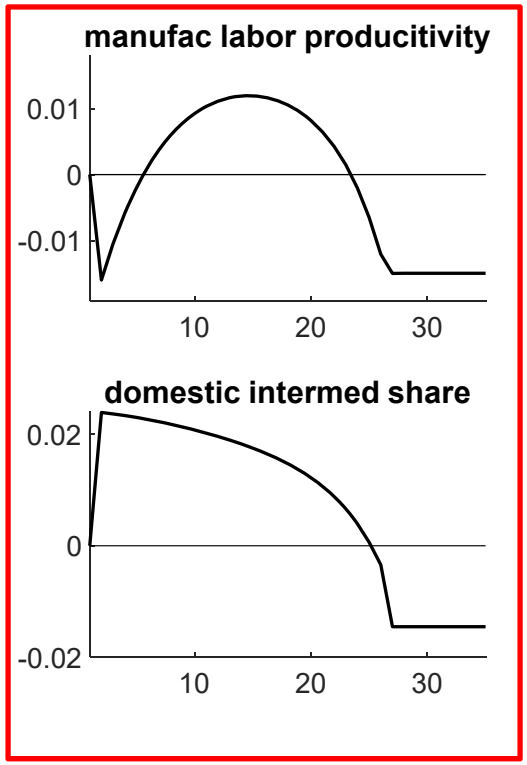


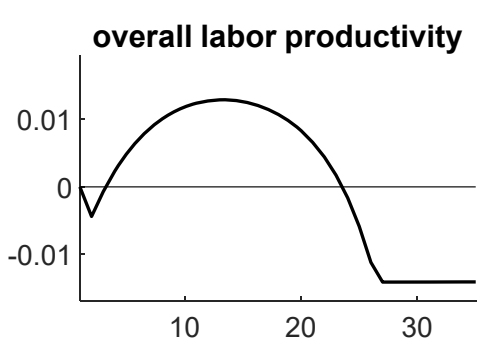


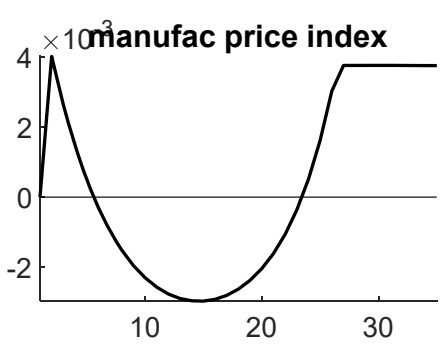


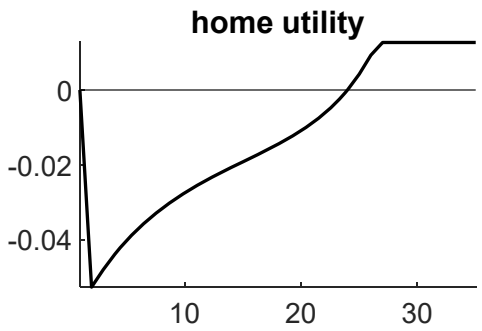
Simulation for Benchmark Model, cont.:

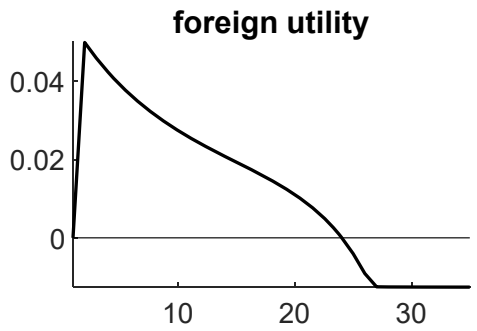
- Manufacturing labor productivity falls initially due to rise in labor inputs, but then rises, mirroring dynamics of firm creation.
- Reinforced by rise in domestic sourcing of intermeds.



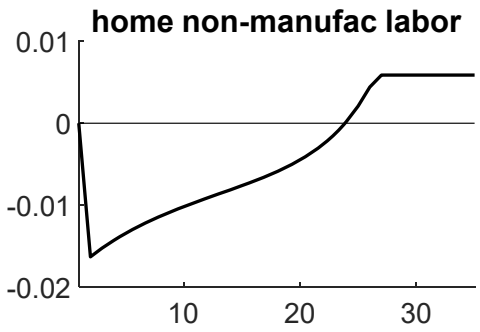


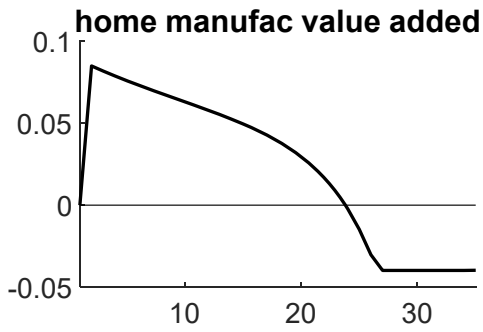


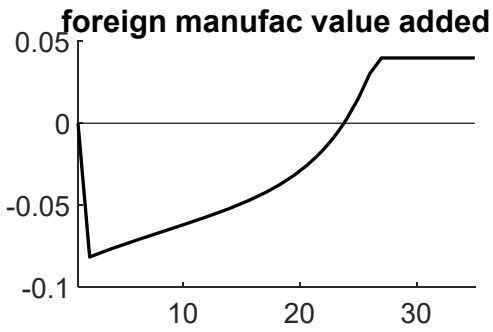




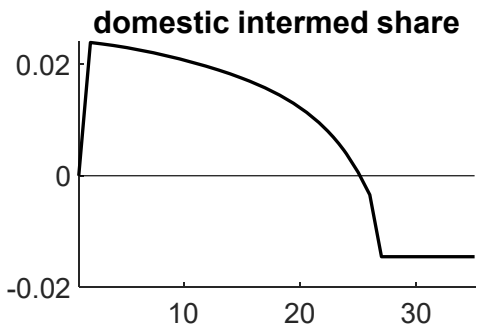
Simulation for Benchmark Model, cont.:

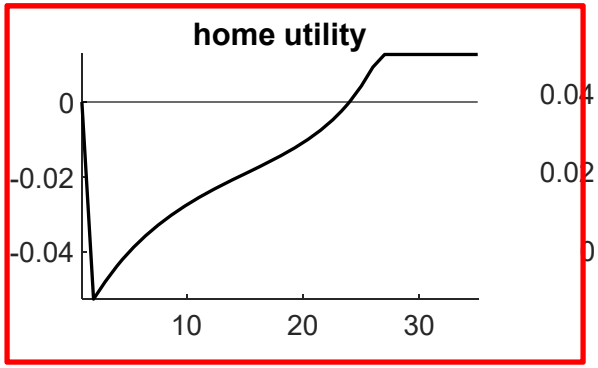


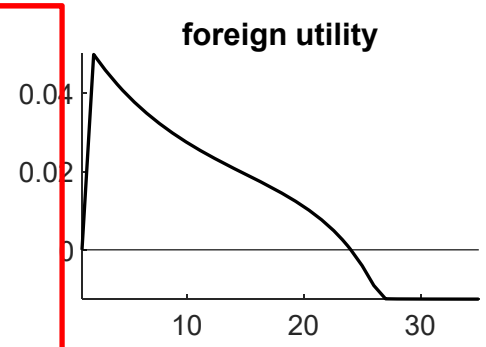




- Short run cost to home utility with long run gain.
- Net drop in home welfare (see below).







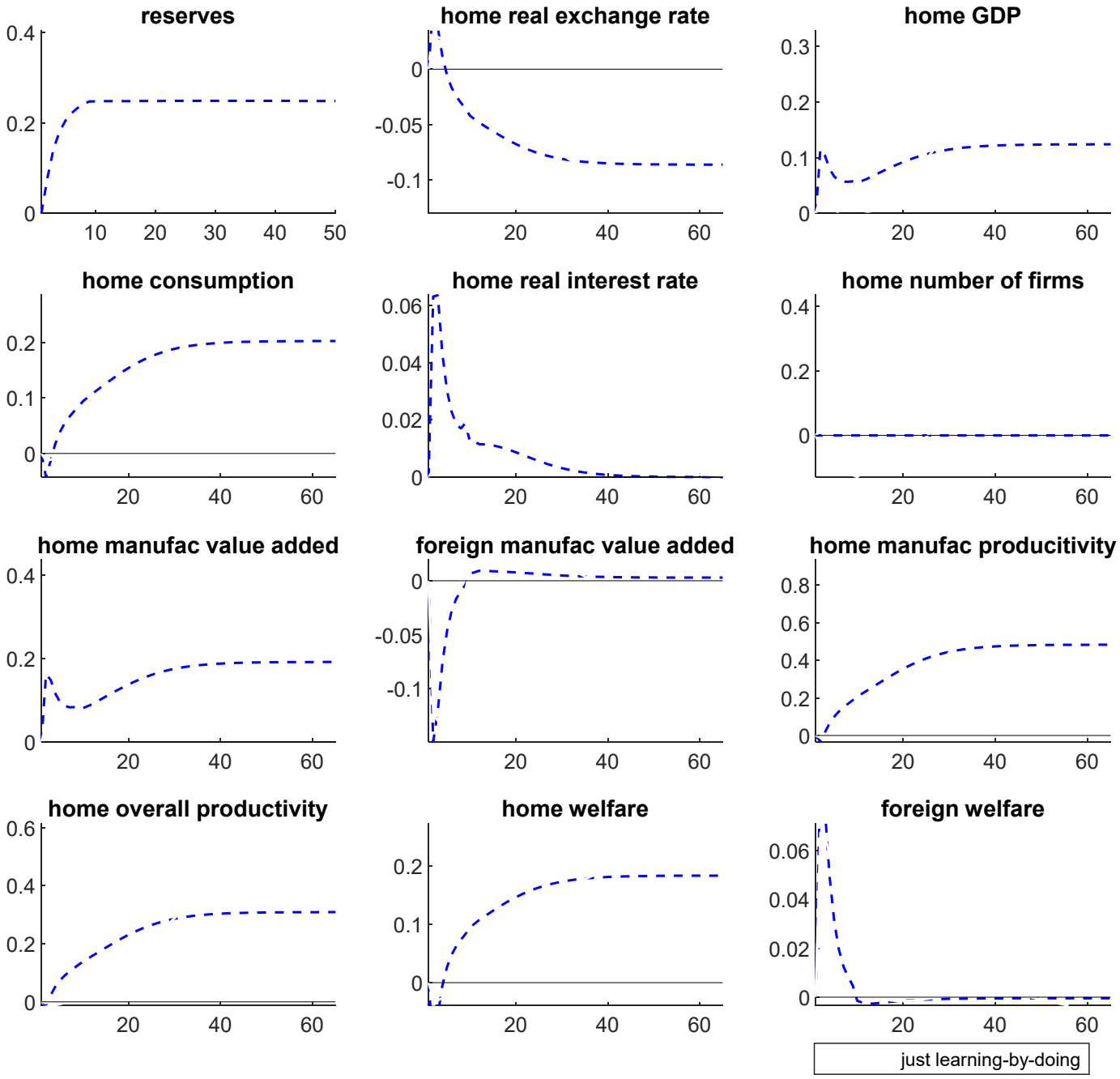
ι

Extension: Learning-by-doing

- Specification emulates Ottonello, et al. (2024): manufacturing firm productivity rises with preceding sectoral production, with upper bound:
- Model: Replace exog. α_T in production with α_{Tt} (ι = 0.27 from Cooper-Johri (JME 2002)).

$$\alpha_{T,t} = \alpha_{T,t-1}\left(y_{Tt-1}/\overline{y}_T\right)^{\iota\left(\overline{\alpha}_T - \alpha_{Tt-1}\right)}$$

- Optimal policy: gov't chooses path of reserves each period to maximize discounted sum of utility in country 1.


reserves
home real exchange rate
home GDP
home consumption
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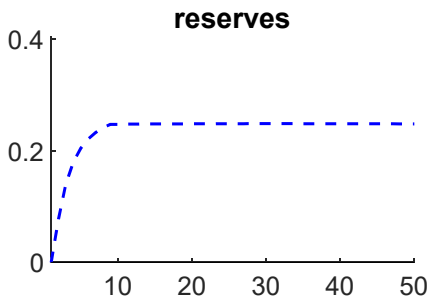
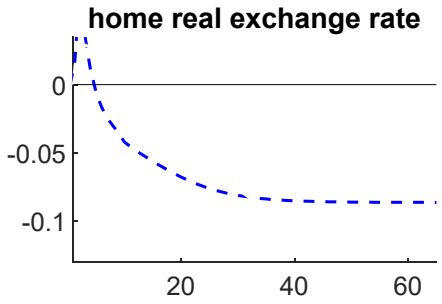
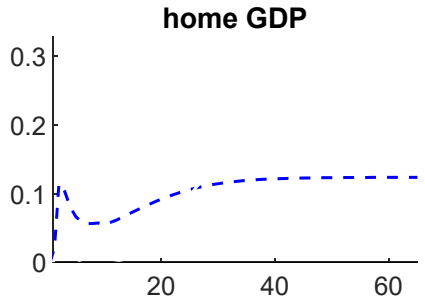
home number of firms
home manufac value added
foreign manufac value added
home manufac producitivity
home overall productivity
home welfare
foreign welfare
just learning-by-doing

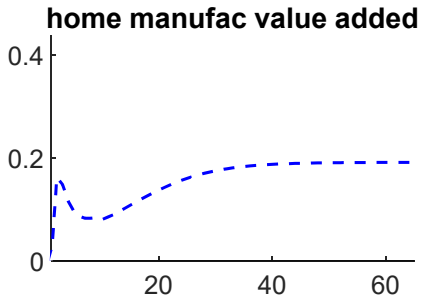


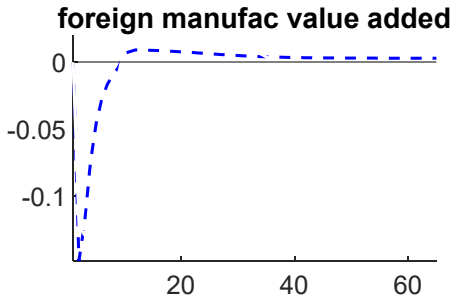


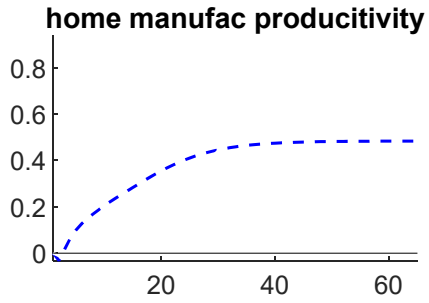


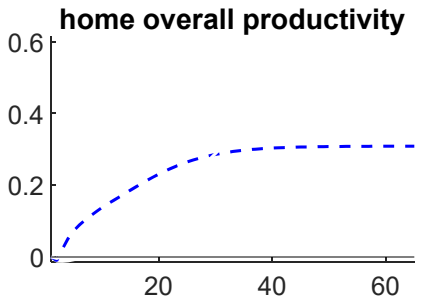
Just learning by doing with no firm dynamics:

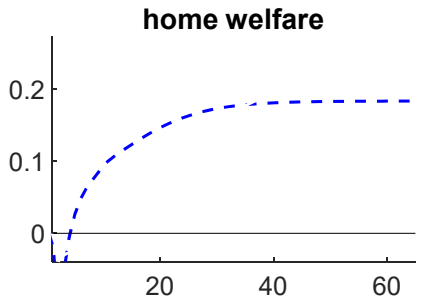
Large and permanent gains in productivity and utility.
Foreign manufacturing falls during period of policy

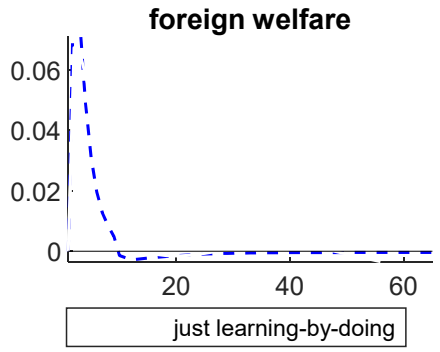


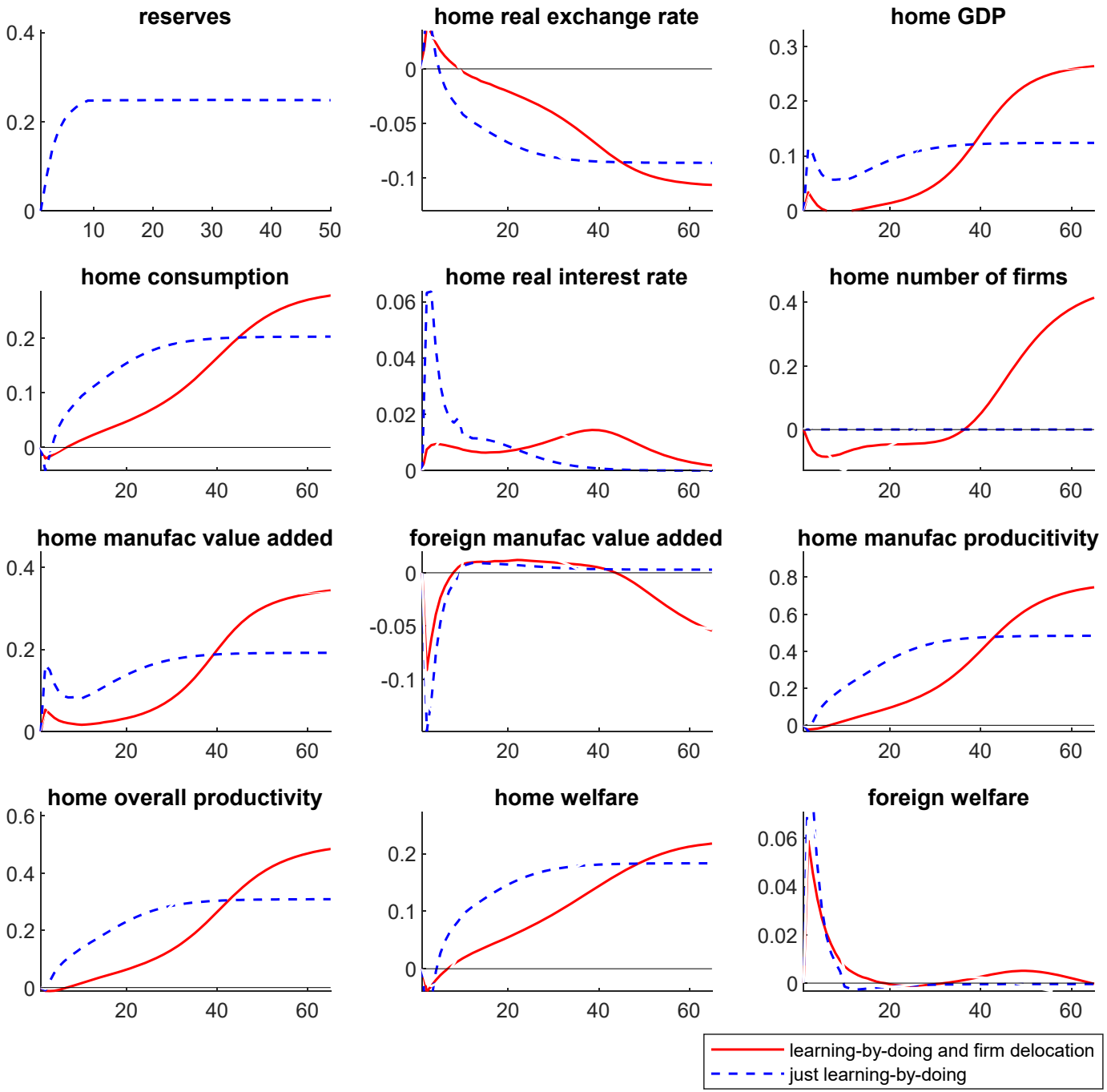











reserves
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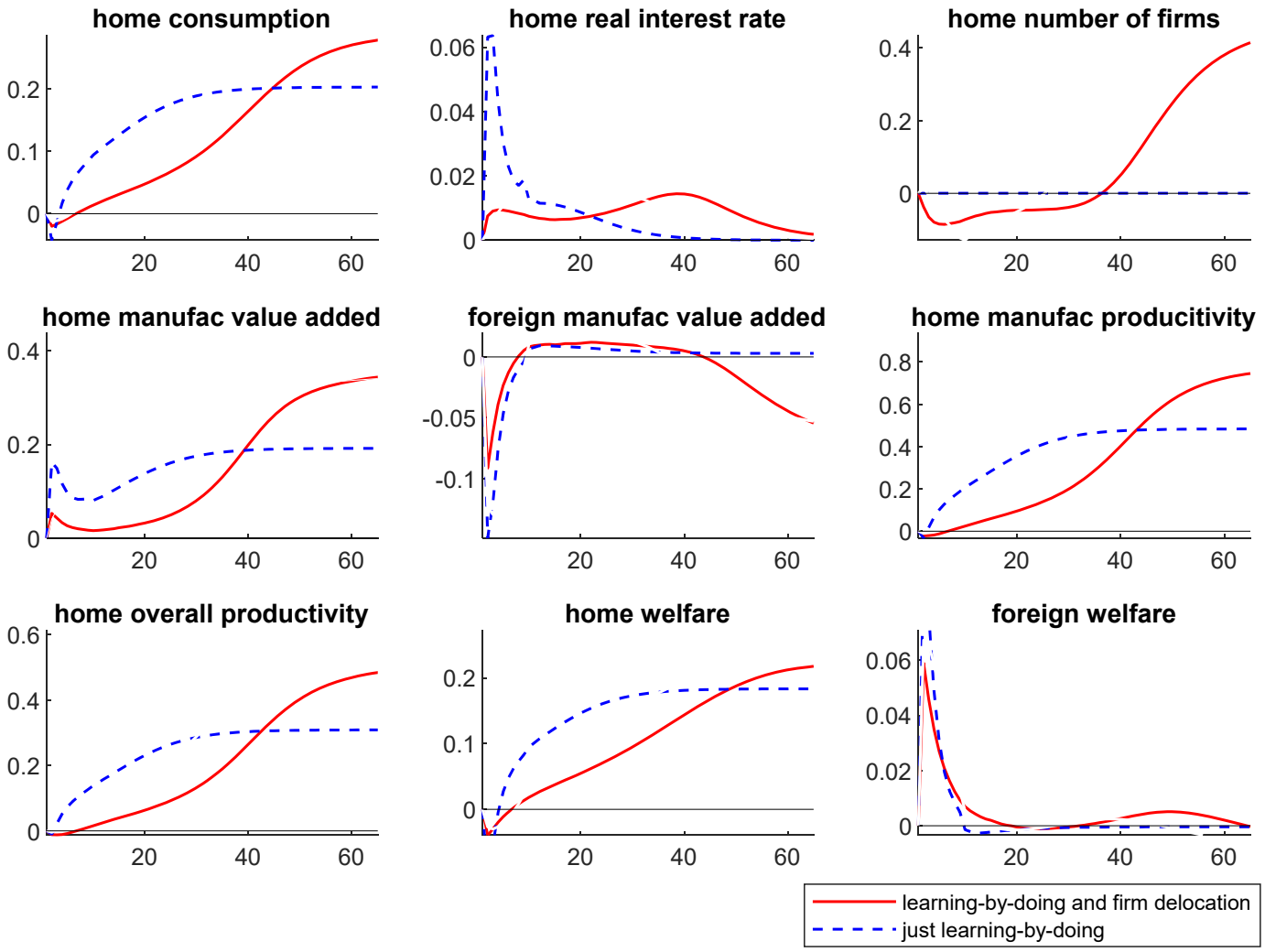
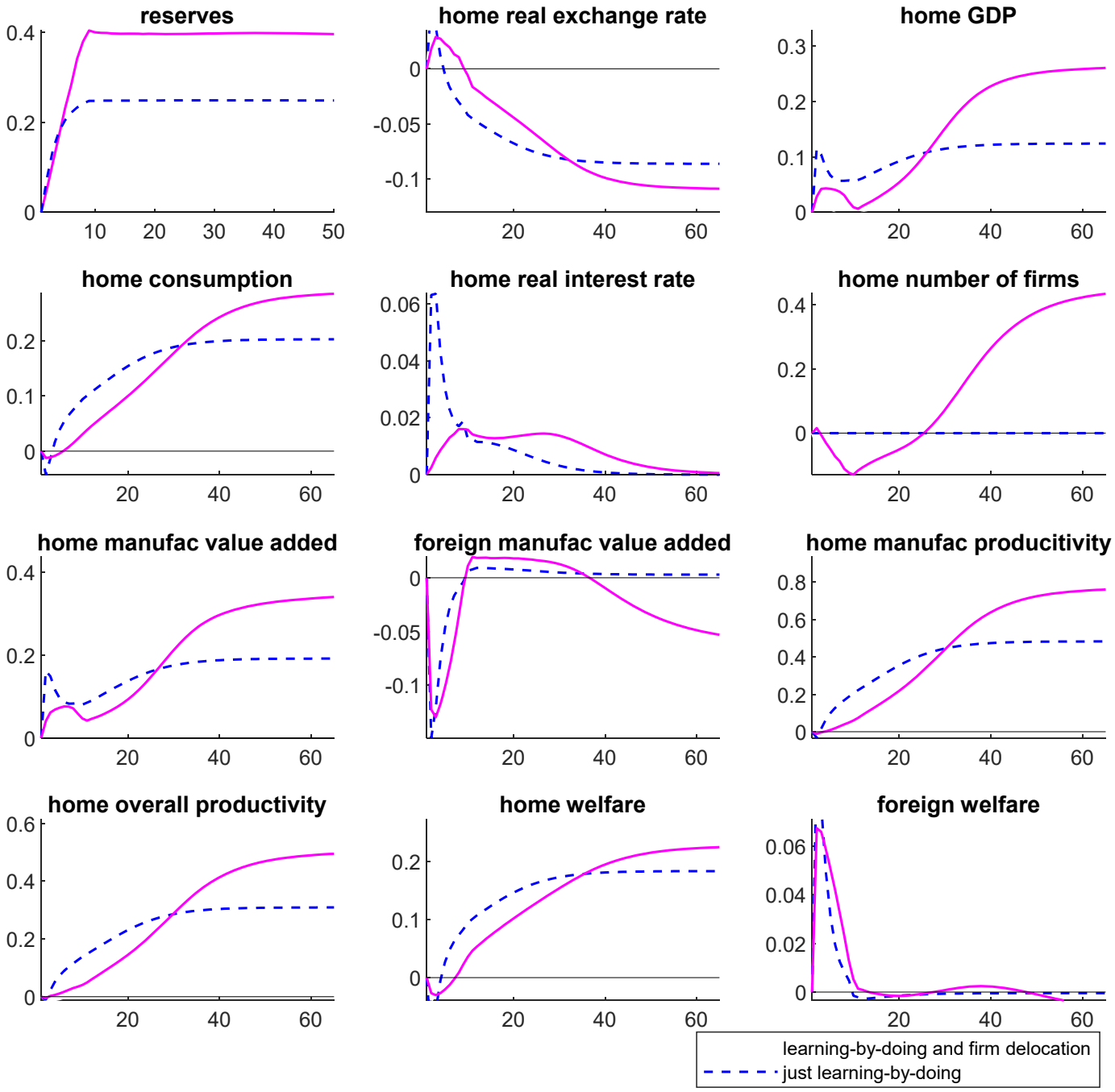
home GDP
home consumption
home real interest rate
home number of firms
home manufac value added
foreign manufac value added
home manufac producitivity
home overall productivity
home welfare
foreign welfare
learning-by-doing and firm delocation
just learning-by-doing

Model with firm dynamics, with same policy.
Firm entry amplifies effects of policy on productivity, welfare, and foreign manufacturing. But takes long time.

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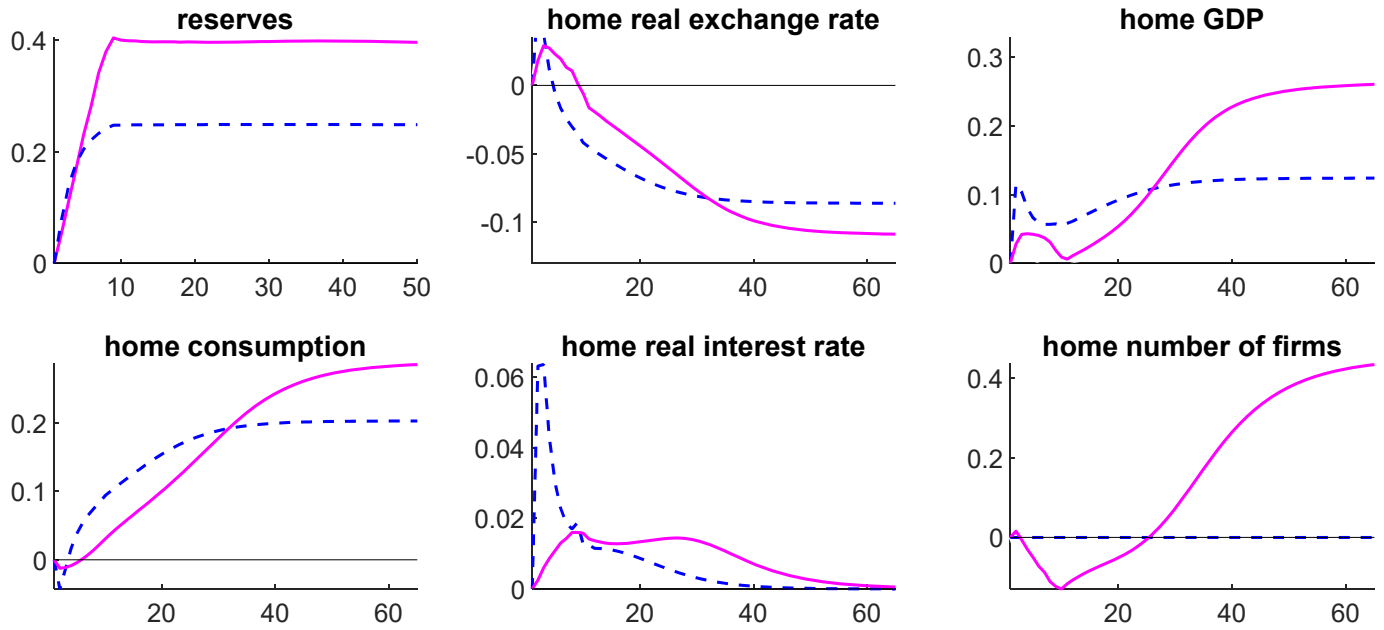


Model with firm dynamics, with distinct optimal policy. Reserve accumulation larger; reach long run steady state sooner.

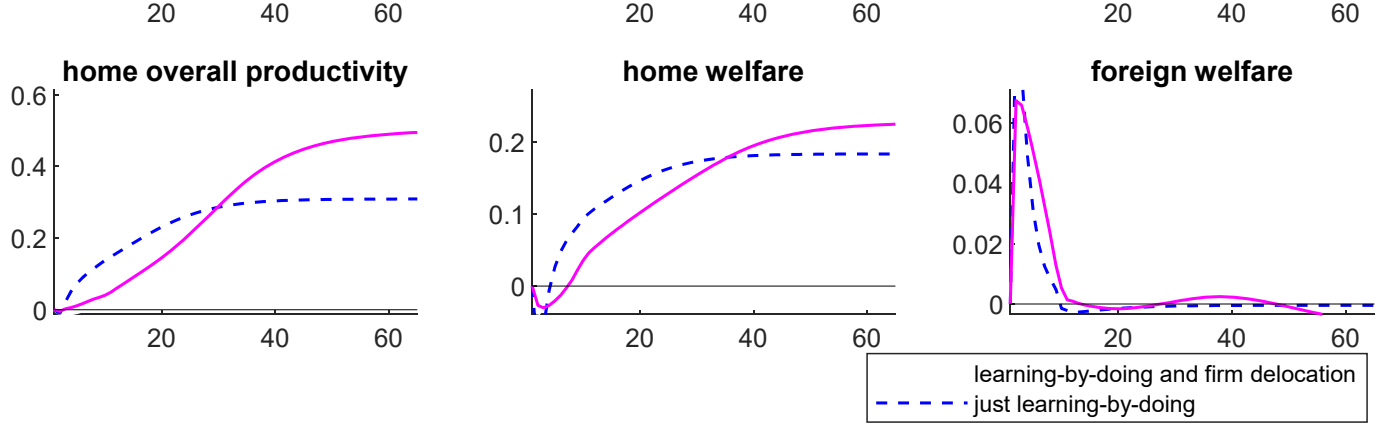


Table 7. Welfare

	Home	Foreign
Constant reserve accumulation policy:		
benchmark economy (delocation)	-0.3531	0.2998
no delocation	-0.3889	0.3749
learning -by-doing (no delocation)	13.1448	0.7692
learning -by-doing and delocation	12.7914	0.6640
Optimized policy		
learning -by-doing (no delocation)	13.4942	0.5706
learning -by-doing and delocation	12.9569	0.5967

The table reports change in household welfare from adopting the stated policy, relagie to the no-policy case. In units of percentage change in steady state consumption

Firm Delocation on own does not raise home welfare for our calibration.
Deindustrialization and polarization might not be reflected in lower foreign welfare.

Conclusions

- Sustained currency undervaluation due to capital account policy can affect longer-run economic features like productivity and structural change.
- Production delocation suggests new mechanism for promoting export-led growth by redirecting supply chains.
- Complementary to learning by doing.
- Amplifies foreign deindustrial'n and polarization.
- Extension: two tradable goods (differentiated and non) may invert delocation mechanism; undervaluation may hurt comp. advg. in differentiated goods due to lower price elasticity.

Extra slides

Table 1. Sample countries (45 countries, 1985-2007)

Panel A. list of countries

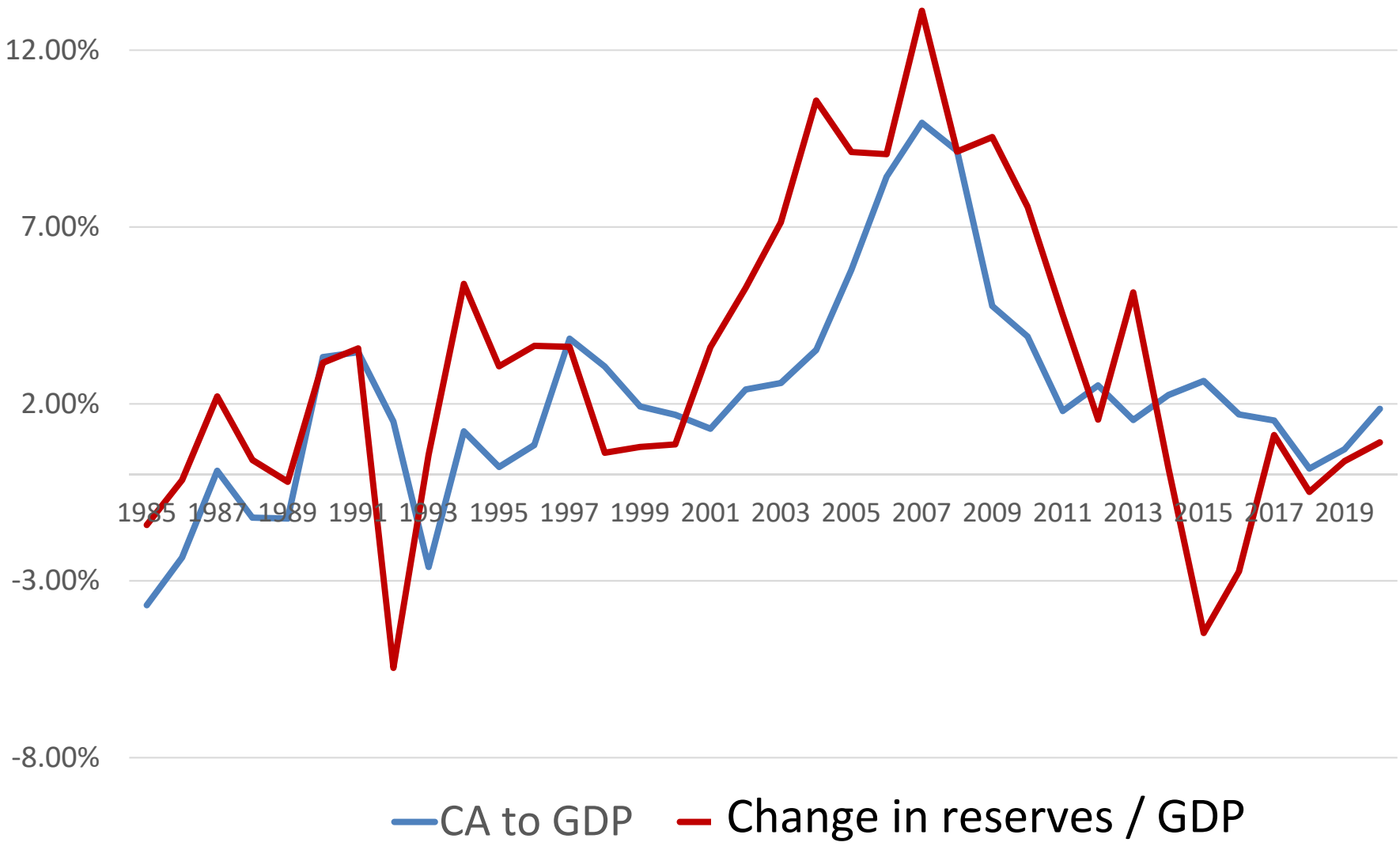
Advanced countries		Emerging market countries	
Australia	Italy*	Argentina	Indonesia
Austria*	Japan*	Bolivia※	Israel⊙
Belgium*	Netherlands*	Brazil	Korea, Rep.*
Canada*	New Zealand※	Chile*	Malaysia
Denmark*	Norway	China*	Mexico*
Finland*	Portugal*	Colombia	Peru*
France*	Spain*	Costa Rica*	Philippines
Germany*	Sweden*	Cyprus*	Russian Federation*
Greece*	Switzerland	Egypt	Singapore
Iceland	United Kingdom*	Hong Kong, China	Thailand
Ireland*	United States*	India*	Turkey
			Venezuela

*domestic intermediate share data are available ※sectoral productivity data is available after 1990. ⊙ setoral productivity data is available after 2000.

Table A.1. Summary statistics based on annual observations (45 countries, 1985-2007)

	Full sample					Emerging markets countries				
Variables	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
(log) manufacturing productivity	795	0.029	0.035	-0.077	0.180	464	0.027	0.041	-0.077	0.180
(log) non-manufacturing productivity	795	0.017	0.023	-0.033	0.122	464	0.021	0.027	-0.033	0.122
Capital controls (CC)	795	0.344	0.349	0	1	464	0.525	0.326	0	1
d.Reserves to GDP	795	0.006	0.016	-0.029	0.109	464	0.010	0.018	-0.029	0.109
CC×d.Reserves to GDP	795	0.003	0.008	-0.022	0.046	464	0.005	0.010	-0.022	0.046
Extensive margins	795	0.217	0.140	0.018	0.599	464	0.156	0.093	0.018	0.494
Intensive margins	795	0.123	0.050	0.026	0.295	464	0.112	0.040	0.026	0.207
# of listed domestic firms	708	822.852	1423.942	12	8090	401	582.451	1018.193	12	5978
Domestic intermediate shares[a]	386	0.855	0.134	0.341	0.990	175	0.883	0.117	0.356	0.986
Private credit to GDP	795	0.741	0.486	0.109	2.681	464	0.538	0.404	0.109	1.649
(log) terms of trade	795	4.631	0.169	3.845	5.178	464	4.619	0.181	3.845	5.178
Institutional quality	795	8.126	2.358	2.9722	12	464	7.172	1.927	2.972	12
Human capital (% of tertiary complete)[b]	795	8.712	5.646	0.7616	24.370	464	6.705	5.229	0.762	24.370
Crisis dummy	795	0.184	0.317	0	1	464	0.276	0.362	0	1

China



Source: Bergin et al. (2023)

Define labor productivity (net of intermediates):

- In manufacturing sector, using value added netting out cost of intermediate inputs

$$LP_{Tt} = \frac{n_{t-1}\left(\left(p_t(h)/p_{Tt}\right)y_t(h) - G_t(h)\right)}{n_{t-1}l_t(h)}$$

- Overall

$$LP_t = \frac{\left(n_{t-1}\left(p_t(h)y_t(h) - p_{Tt}G_t(h)\right)_t + p_{Nt}y_{Nt}\right)/P_t}{n_{t-1}l_t(h) + L_{Nt}}$$

Analytical Relationship:

- Substitute into LP_T definition: production function, input demand, and firm price setting:

$$LP_{T,t} = \left(\frac{\phi}{\phi - 1} - \zeta\right)\left(\frac{1}{1-\zeta}\right)\frac{W_t}{P_{T,t}}$$

where $\left(\frac{\phi}{\phi - 1} - \zeta\right) > 0, \quad \left(\frac{1}{1-\zeta}\right) > 0$

- Says labor productivity rises when price of materials inputs falls relative to wage.
- And effect rises with intermediates share, $\zeta \to 1$.