Modelling Oil Prices in a Dynamic General Equilibrium Model with Free Entry

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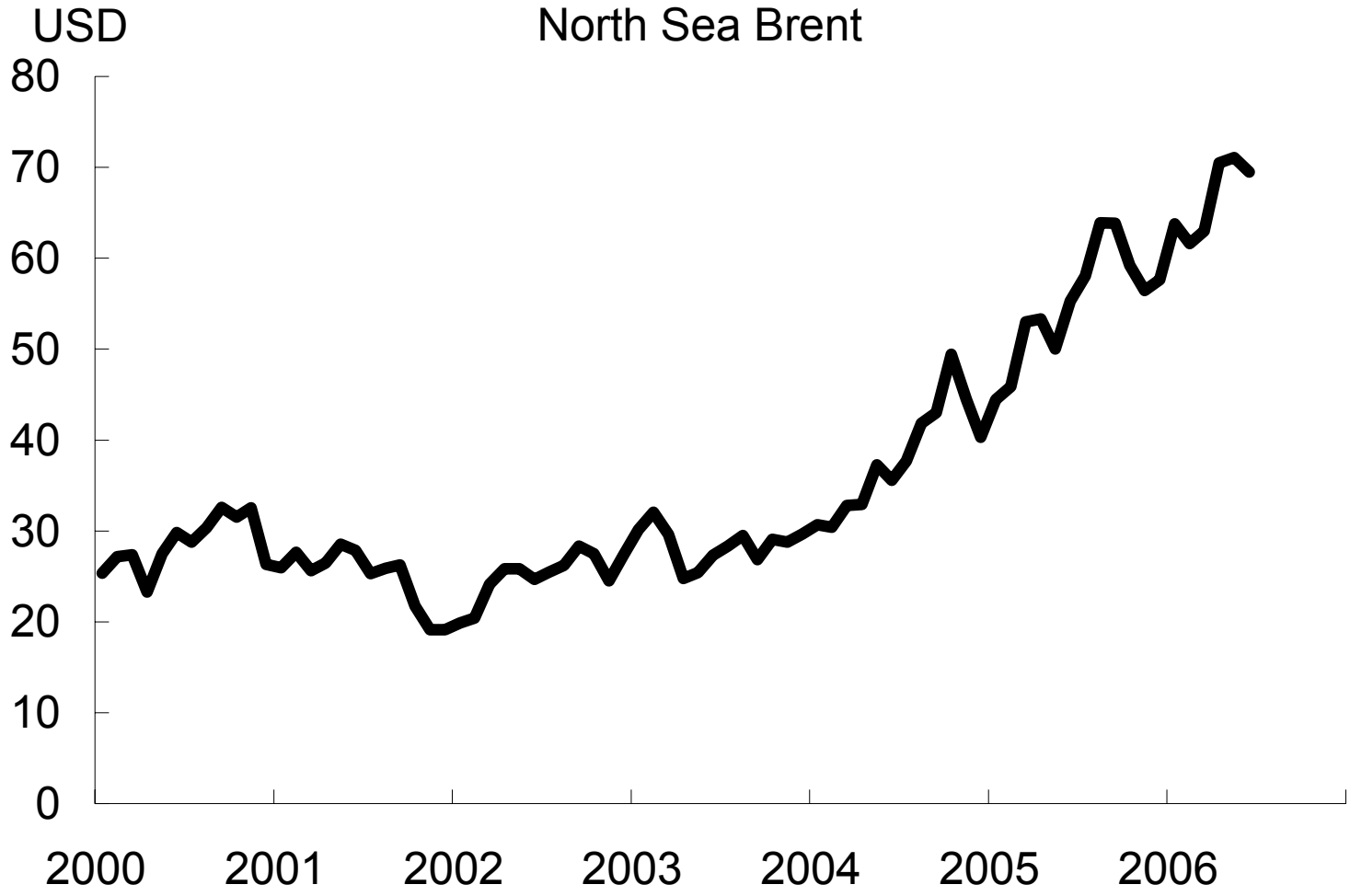
Motivation


USD
North Sea Brent
80
70
60
50
40
30
20
10
0
2000
2001
2002
2003
2004
2005
2006

OPEC Statement

- "The Conference also noted that, similarly, world crude oil prices continued to remain high and volatile as a consequence of abiding concern over the lack of effective global oil refining capacity, in the short and medium term, coupled with anxiety about the ability of oil producers to meet anticipated, future oil demand. This price volatility is being exacerbated by geopolitical developments and speculation in the oil futures markets."

Aim of the Paper

- To show the theoretical mechanism of soaring oil prices, its transmission and welfare implications in a DSGE model with Free Entry
- To demonstrate how we can express the realistic scenario, "anxiety about the ability of oil producers to meet anticipated, future oil demand" employing the expectation shock

Outline

1. Introduction
2. Mechanism of Free Entry
3. Model
4. Scenarios for Soaring Oil Prices
   - Contemporaneous Shocks
   - Expectation Shocks
5. Conclusion

Mechanism of Free Entry

Why endogenous variety?

- Strong empirical evidence that entry dynamics (extensive margin) co-move with the business cycle
- Serve as an amplification and propagation mechanism for real shocks, and affect the transmission mechanism for monetary policy
- Analyze the effect of increased population on oil demand as well as the home market effect

Dixit-Stiglitz aggregator

- Standard CES aggregator

$$Y_t = \left[\int_0^1 y_t(i)^{1-\frac{1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}$$

- CES aggregator with endogenous variety

$$Y_t = n_t^{\gamma - \frac{\theta}{\theta-1}} \left[\int_0^{n_t} y_t(i)^{1-\frac{1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}$$

$$\text{If } \gamma > \frac{\theta}{\theta-1}, \text{ taste for variey exists.}$$

n is determined by free entry (zero profit) condition.

Free Entry Condition

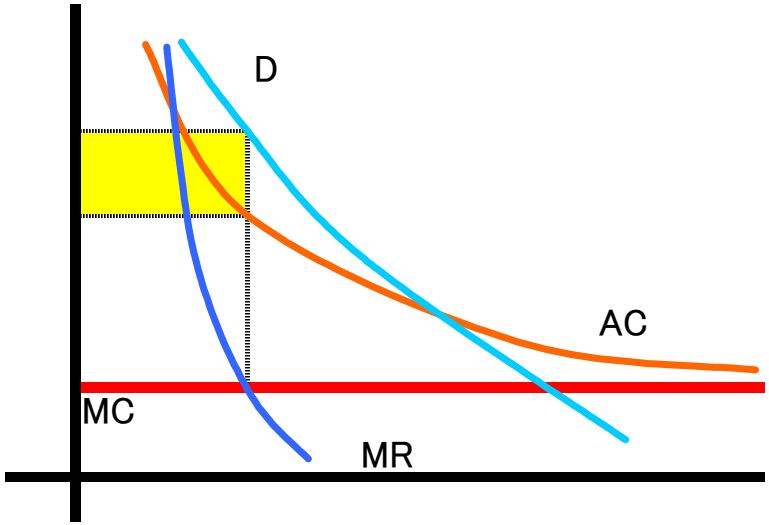
- Zero profit condition determines output per firm.

$$\max_{y}\left[\left(p-mc\right)y-\overline{F}\right]=0,$$

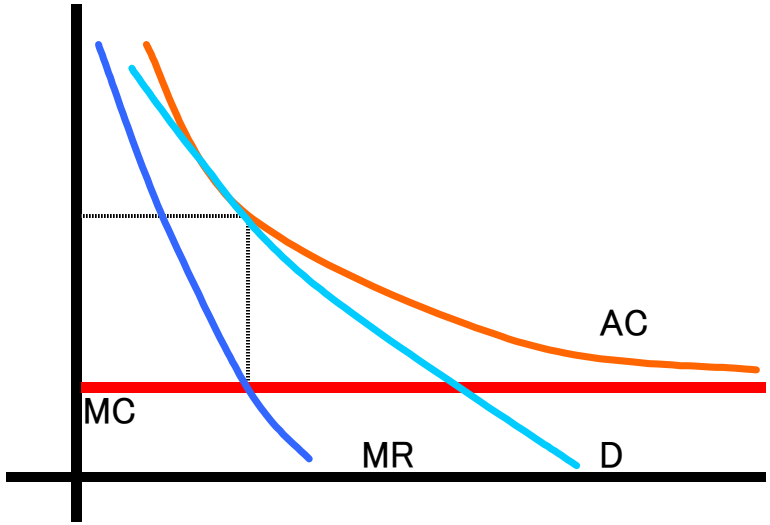
$$\text{where } y=\bar{z}h \text{ and } p=\frac{\theta}{\theta-1}mc \quad \Rightarrow \quad y^{*}=\left(\theta-1\right)\frac{\overline{F}}{MC}$$

- Resource constraint (for labor market) determines the number of firms in a symmetric equilibrium (inelastic labor supply is assumed)

$$\overline{L}=hn=\frac{y^{*}}{\bar{z}}n$$



Short-run Partial Equilibrium



Long-run Partial Equilibrium

Free entry induces leftward shifts of demand curve per firm

Monetary Policy Implication

- Increase in standard technology
  - decrease in marginal cost
  - decrease in inflation rates
- Decrease in fixed cost (another form of technology), if no taste for variety
  - no changes in marginal cost
  - no changes in (average) inflation rates

- However, since the number of firm is a state variable due to time-to-build constraint, in the short-run, decrease in fixed cost will
  - increase labor demand
  - increase real wage
  - increase marginal cost
  - increase (average) inflation
- Something similar to technology shock results in positive inflation rates!

Model

Endogenous variety model

- Dynamic and closed economy model
  - Bergin and Corsetti (2006)
    - analyze stabilization policy issues with endogenous firm entry model.
  - Mancini-Griffoli (2006)
    - By assuming that only entry costs are sticky, monetary shock affects the determination of creating new firms, and generate persistent as well as hump-shaped responses of consumption, output and new firm entry, as observed in the data.
  - Bilbiie, Ghironi and Melitz (2005)
    - focusing on cyclical properties of the macroeconomic process with firm entry.

- Dynamic and multi-country model with heterogeneity
  - Ghironi and Melitz (2005)
    - extend the Melitz (2003) model (with heterogeneity in productivity between firms) to a dynamics framework.
    - give precise micro foundations to the Harrod-Balassa-Samuelson effect.
- Static and multi-county model
  - Corsetti, Martin and Pesenti (2006)
    - analyze the international transmission and welfare implication of two types of productivity gain; reducing the marginal costs of producing goods and lowering the cost of firms' entry.

The model

- Our model is based on recent literature, which combines New Open Economy Macroeconomics initiated by Obstfeld and Rogoff (1995)
- Dynamic parts of this model are mostly based on the Global Economy Model (GEM) by Laxton and Pesenti (2002).

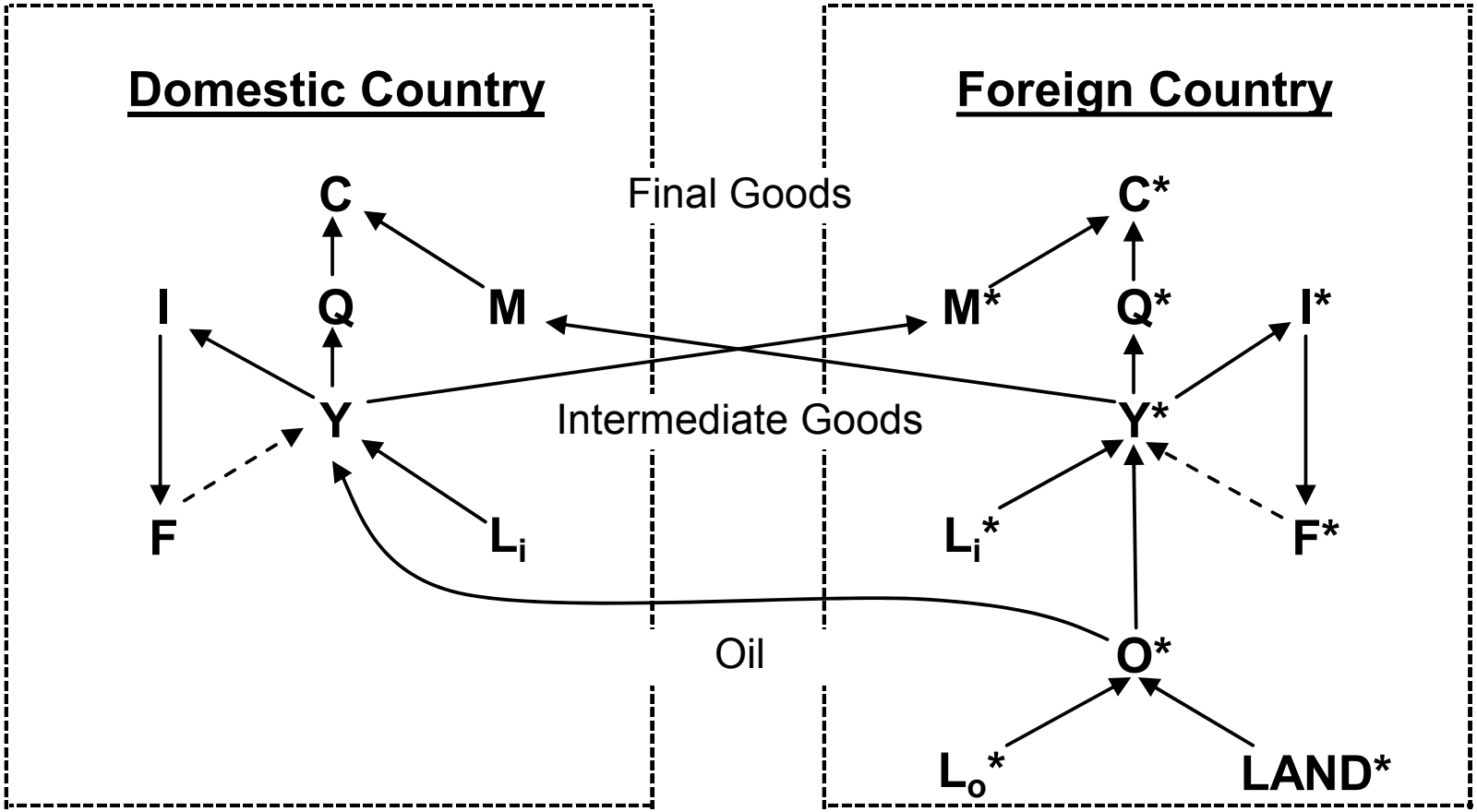
- Since heterogeneous technology level among firms is not considered, our model can be interpreted as a dynamic extension of Corsetti, Martin and Pesenti (2005) or a multi-country extension of Bilbiie, Ghironi and Melitz (2005) and Bergin and Corsetti (2006).
- Our model incorporates nominal rigidities in price and wage settings, and dynamic adjustment costs.

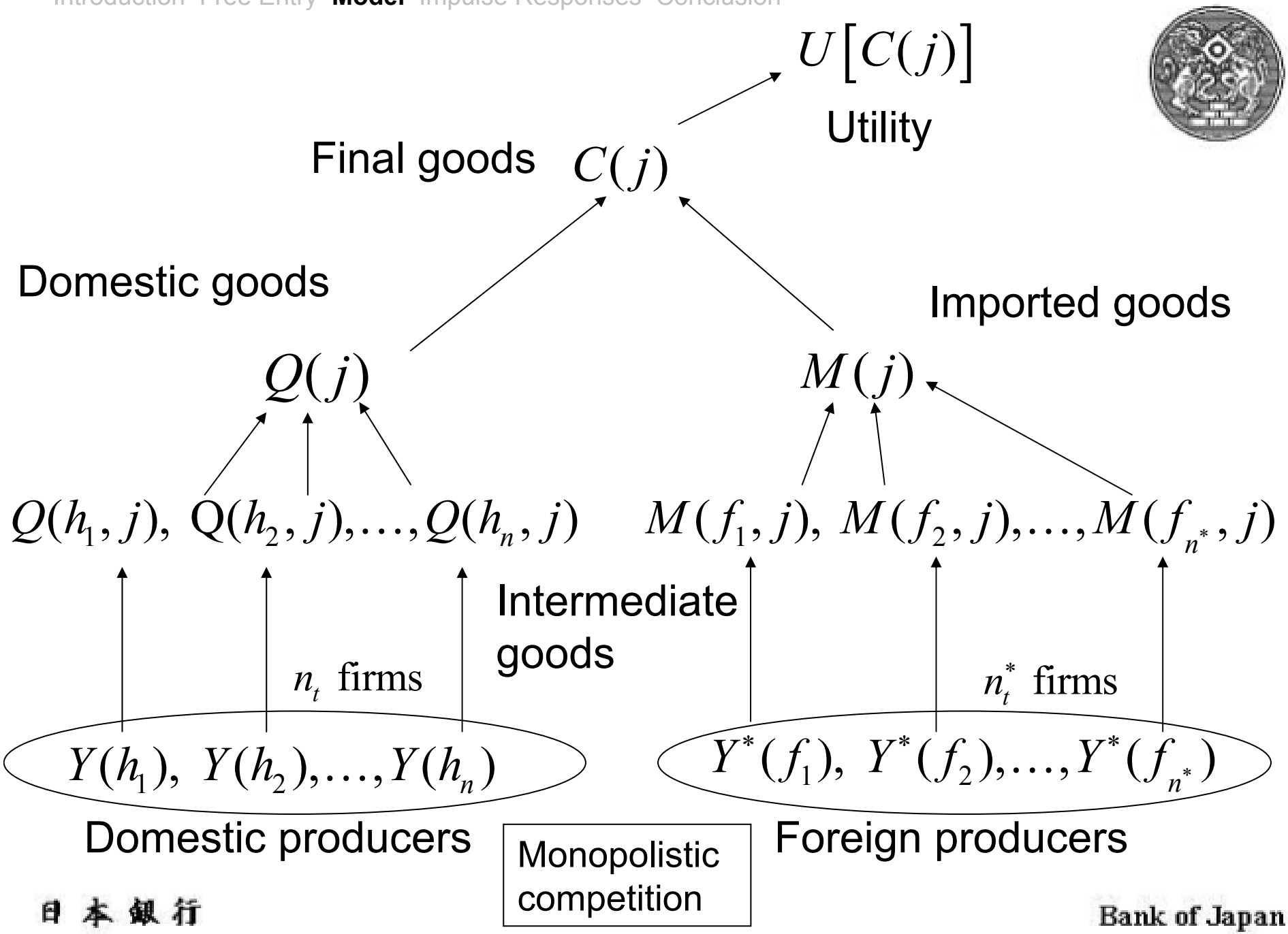
Features

- A two-country (economy) model, which consists of home and foreign countries.
- Agents are households, firms, and the monetary authority.
- Households maximize their welfare from consumption of final goods and leisure after differentiated labor supply to domestic firms.
- Households own their country's firms and land (oil well). They receive profits as a dividend and land rent.

- There are two types of firms, intermediate goods firms and raw material goods (oil) firms.
- The intermediate goods market is monopolistically competitive. Each firm produces differentiated products using labor and raw material. Intermediate firm size and number are endogenously determined.
- Raw material goods market is perfectly competitive. Each firm produces raw materials using labor and land (oil well).

Model Structure




$U[C(j)]$
Utility
Final goods $C(j)$
Domestic goods
Imported goods
$Q(j)$
$M(j)$
$Q(h_1, j)$, $Q(h_2, j), \ldots, Q(h_n, j)$
$M(f_1, j)$, $M(f_2, j), \ldots, M(f_{n^*}, j)$
Intermediate goods
n_t firms
n_t^* firms
$Y(h_1)$, $Y(h_2), \ldots, Y(h_n)$
$Y^*(f_1)$, $Y^*(f_2), \ldots, Y^*(f_{n^*})$
Domestic producers
Monopolistic competition
Foreign producers

Final goods

Composite of final goods:

$$C_t(j) = \left[\nu^{\frac{1}{\varepsilon}} Q_t(j)^{1-\frac{1}{\varepsilon}} + (1-\nu)^{\frac{1}{\varepsilon}} M_t(j)^{1-\frac{1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

C(j) : Final goods consumed by household *j*

Q(j) : Aggregations of a basket of domestic goods

M(j) : Aggregations of a basket of foreign goods.

$$Q_t(j) \equiv A_{Q,t}\left[\int_0^{n_t} Q_t(h,j)^{1-\frac{1}{\theta}}\, dh\right]^{\frac{\theta}{\theta-1}},$$

$$M_t(j) \equiv A^*_{Q,t}\left[\int_0^{n^*_t} M_t(f,j)^{1-\frac{1}{\theta^*}}\, df\right]^{\frac{\theta^*}{\theta^*-1}},$$

Production technology

Intermediate goods:

$$Y_t(h) = Z_t \left[(1-\alpha)^{\frac{1}{\xi}} l_t^I(h)^{1-\frac{1}{\xi}} + \alpha^{\frac{1}{\xi}} O_t(h)^{1-\frac{1}{\xi}} \right]^{\frac{\xi}{\xi-1}}$$

Raw material goods (oil):

$$O_t^*(s) = Z_t^{O*} \left[(1-\alpha^{O*})^{\frac{1}{\xi^O}} l_t^{O*}(s)^{1-\frac{1}{\xi^{O*}}} + \alpha^{*\frac{1}{\xi^O}} LAND_t^{*1-\frac{1}{\xi^{O*}}} \right]^{\frac{\xi^{O*}}{\xi^{O*}-1}}$$

$Y(h)$:Production of intermediate goods.

$l^I(h)$, $l^O(s)$: labor input

$O(h)$: Oil input

$LAND$: land input (oil well)

Price setting equations

Thus firm h's objective function:

$$\max_{p_\tau(h),p^*_\tau(h)} \mathrm{E}_t \sum_{\tau=t}^{\infty} (1-\delta)^{\tau-t} D_{t,\tau}(j)\, \Pi_\tau(h)$$

$$\Pi_t(h) \equiv [p_t(h) - \Psi_t] \int_0^{L_t} Q_t(h,j)\, dj\, [1 - \Gamma_{Q,t}(h)]$$
$$+ [\mathcal{E}_t p^*_t(h) - \Psi_t(1+\tau)] \int_0^{L^*_t} M^*_t(h,j^*)\, dj^*\, [1 - \Gamma^*_{M,t}(h)] .$$

By solving for the first order condition with respect to $p_t(h)$:

$$0 = [1 - \Gamma_{Q,t}(n)]\, [p_t(h)(1-\theta) + \theta\Psi_t]$$
$$- [p_t(h) - \Psi_t] \frac{\phi_Q p_t(h)/p_{t-1}(h)}{P_{Q,t-1}/P_{Q,t-2}} \left[\frac{p_t(h)/p_{t-1}(h)}{P_{Q,t-1}/P_{Q,t-2}} - 1\right]$$
$$+ \mathrm{E}_t (1-\delta_D) D_{t,t+1} [p_{t+1}(h) - \Psi_{t+1}]$$
$$\times \frac{\int_0^{L_{t+1}} Q_{t+1}(h,j)\, dj}{\int_0^{L_t} Q_t(h,j)\, dj} \frac{\phi_Q p_{t+1}(h)/p_t(h)}{P_{Q,t}/P_{Q,t-1}} \left[\frac{p_{t+1}(h)/p_t(h)}{P_{Q,t}/P_{Q,t-1}} - 1\right]$$

Intermediate goods production: Free entry and value of firm

Expected profit of firm h at t

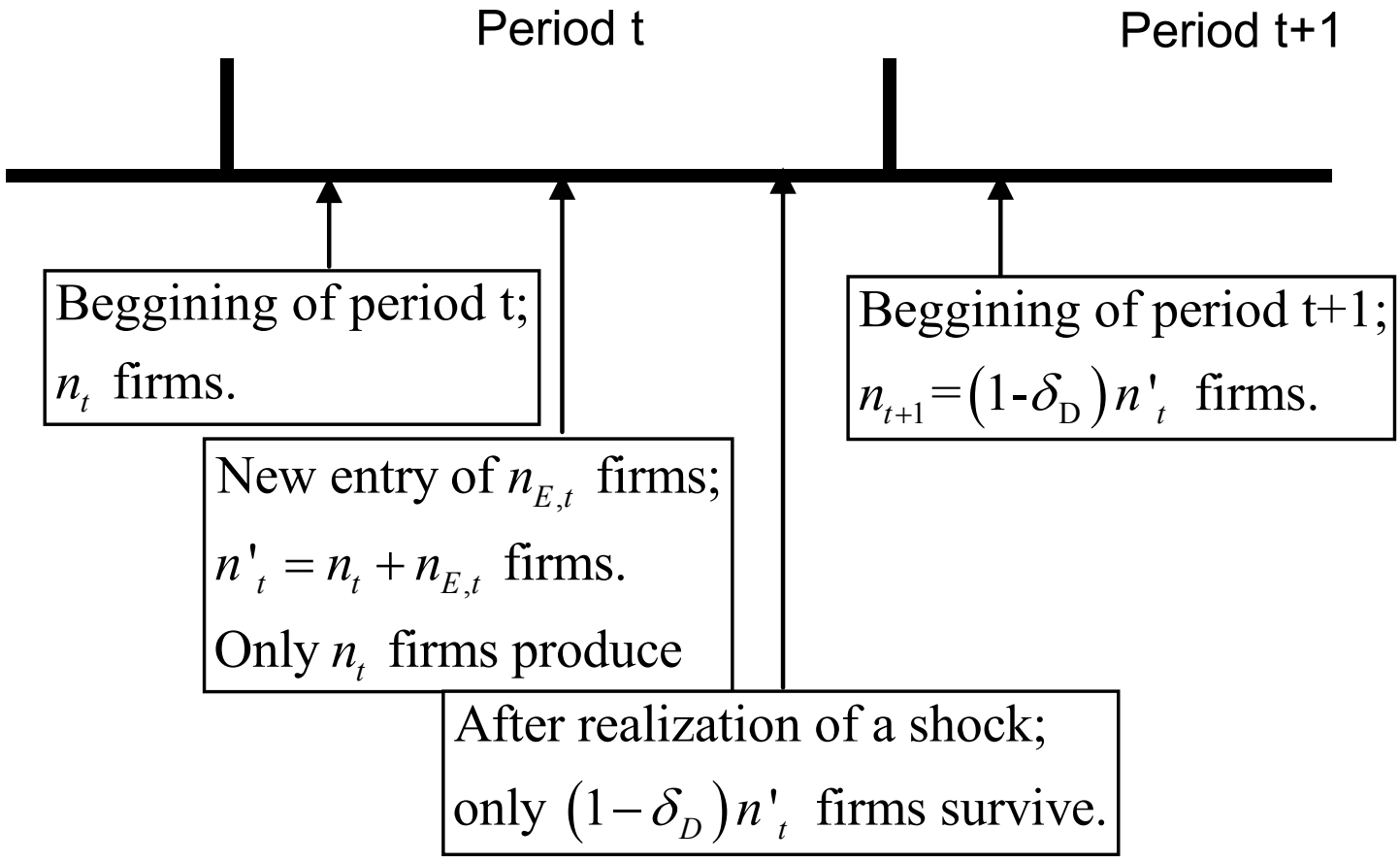
$$\varpi_t(h) = \mathrm{E}_t \sum_{\tau=t}^{\infty} (1-\delta)^{\tau-t} D_{t,\tau}(j)\, \Pi_\tau(h)$$

Free entry condition

Firms enter the market until the fixed entry cost becomes equal to the expected profit. Hence, free entry condition is obtained as:

$$\varpi_t(h) = f_{E,t}\Psi_t.$$

Timing of entry and exit



Household: Utility function

Utility function:

$$\mathrm{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left\{ U_\tau \left[C_\tau (j) \right] - V_\tau \left[l_\tau (j) \right] \right\},$$

$$U_t \left[C_\tau (j) \right] = Z_{U,t} \frac{(1-b_C)^\sigma \left[C_t (j) - b_C C_{t-1} (j) \right]^{1-\sigma} - 1}{1-\sigma},$$

$$V_t \left[l_\tau (j) \right] = Z_{V,t} \frac{(1-b_l)^{-\zeta} \left[l_t (j) - b_l l_{t-1} (j) \right]^{1+\zeta}}{1+\zeta}.$$

Budget constraint

$$\begin{aligned} & \mathcal{E}_t B_{F,t+1} (j) + B_{H,t+1} (j) + x_{t+1} (j) \int_0^{n_t'} \varpi_t (h) \, dh \\ \leq \; & (1+i^*) \left[1 - \Gamma_{B,t} (j) \right] \mathcal{E}_t B_{F,t} (j) + (1+i_t) B_{H,t} (j) \\ & + W_t (j) \, l_t (j) \left[1 - \Gamma_{W,t} (j) \right] \\ & + x_t (j) \int_0^{n_t} \left[\Pi_t (h) + \varpi_t (h) \right] dh \\ & - P_t C_t (j) . \end{aligned}$$

Household: First order conditions

Euler equation for bond

$$1 = (1 + i_t) E_t D_{t,t+1}(j) = (1 + i_t^*) [1 - \Gamma_{B,t+1}(j)] \mathrm{E}_t \left[D_{t,t+1}(j) \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \right],$$

Euler equation for share

$$\varpi_t(h) = (1 - \delta) \mathrm{E}_t D_{t,t+1}(j) [\Pi_{t+1}(h) + \varpi_{t+1}(h)].$$

Wage setting equation

$$\begin{aligned} \psi_t \frac{V_t'(j)}{U_t'(j)} \frac{P_t}{W_t(j)} &= (\psi_t - 1)[1 - \Gamma_{W,t}(j)] + \left[W_t(j) \frac{\partial \Gamma_{W,t}(j)}{\partial W_t(j)} \right] \\ &\quad + \mathrm{E}_t \left[D_{t,t+1}(j) \frac{l_{t+1}(j)}{l_t(j)} W_{t+1}(j) \frac{\partial \Gamma_{W,t}(j)}{\partial W_t(j)} \right], \end{aligned}$$

Stochastic discount factor

$$D_{t,\tau}(j) \equiv \beta^{\tau - t} \frac{P_t U'[C_\tau(j)]}{P_\tau U'[C_t(j)]}.$$

Monetary policy rule

There is no tax collection. The monetary authority follows this simple instrument rule:

$$
\begin{aligned}
(1+i_{t+1})^4 - 1 \;=\; & \omega_i \left[(1+i_t)^4 - 1\right] + (1-\omega_i)\left[(1+\mathrm{E}_t i_{t+1})^4 - 1\right] \\
& + \omega_1 E_t \left(\frac{P_{t+\tau}}{P_{t+\tau-4}} - \Pi_{t+\tau} \right).
\end{aligned}
$$

Market clearing conditions

Intermediate goods market clearing:

$$Y_t(h) = \int_0^{L_t} Q_t^D(h,j)dj + (1+\tau)\int_0^{L_t^*} M_t^{*D}(h^*,j)dj.$$

Raw materials (Oil) market clearing:

$$O_t^*(s^*) = \int_0^{n_t^*} O_{Q,t}^*(f)df + \int_0^{n_{E,t}^*} O_{Q,t}^*(e^*)de^* + (1+\tau_t^*)\left[\int_0^{n_t} O_{M,t}(h)dh + \int_0^{n_{E,t}} O_{M,t}(e)de\right].$$

Labor market clearing:

$$l_t(j) = \int_0^{n_t} l_t^I(h,j)dh + \int_0^1 l_t^O(s,j)\,ds + n_{E,t}\int_0^{n_{E,t}} l_{E,t}(e,j)\,de,$$

Bond market clearing:

$$\int_0^{L_t} B_{H,t}(j)dj = 0,$$

$$\int_0^{L_t} B_{F,t}(j)dj + \int_0^{L_t^*} B_{F,t}^*(j^*)dj^* = 0.$$

Scenarios for Soaring Oil Prices

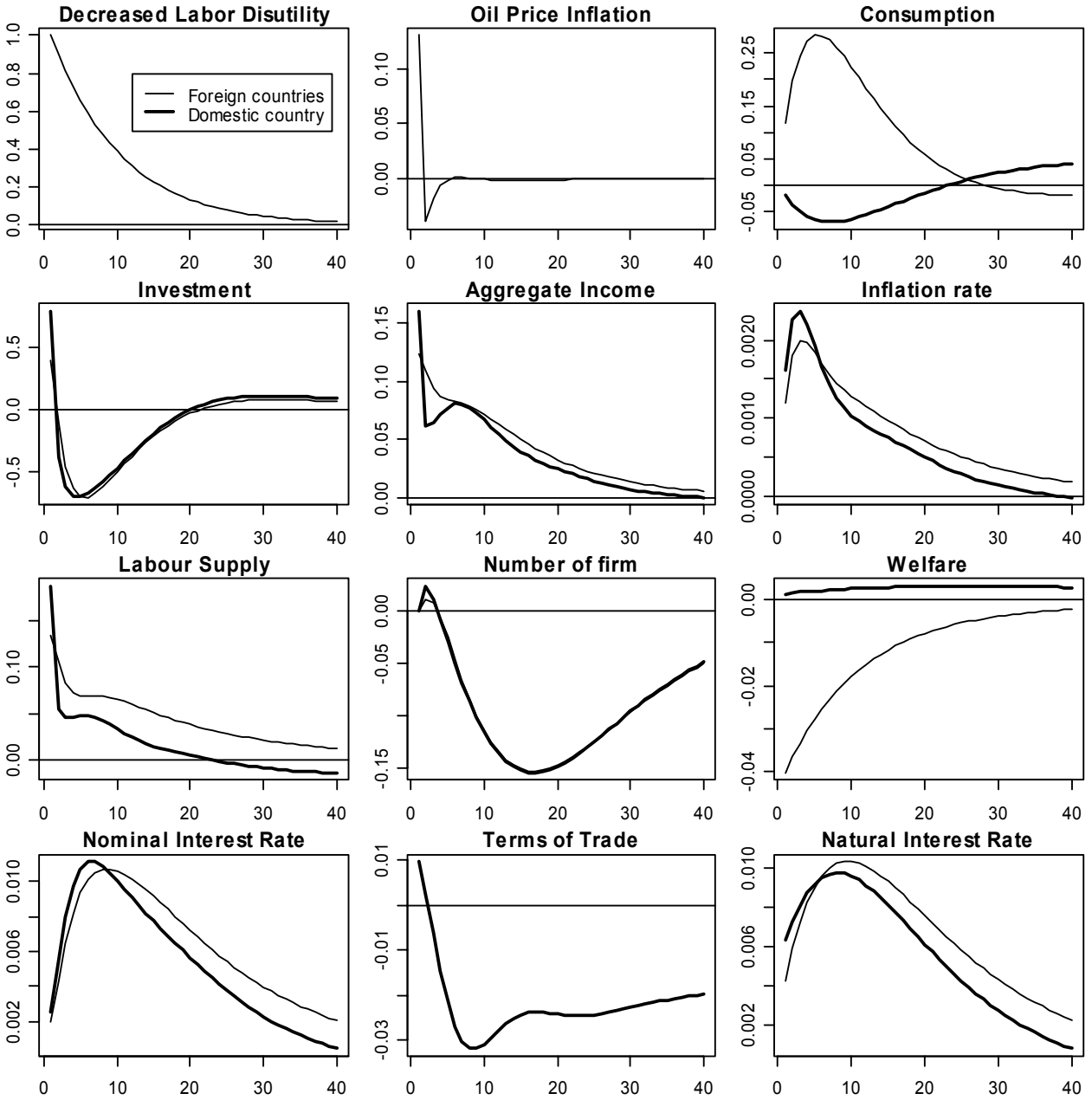
Natural Rate of Interest

- We compute the natural rate of interest by eliminating all nominal rigidities.
- Alternative is to compute by treating responses of foreign variables as exogenous and eliminating domestic nominal rigidities.
- We have found almost no significant differences between them.

Contemporaneous Shocks

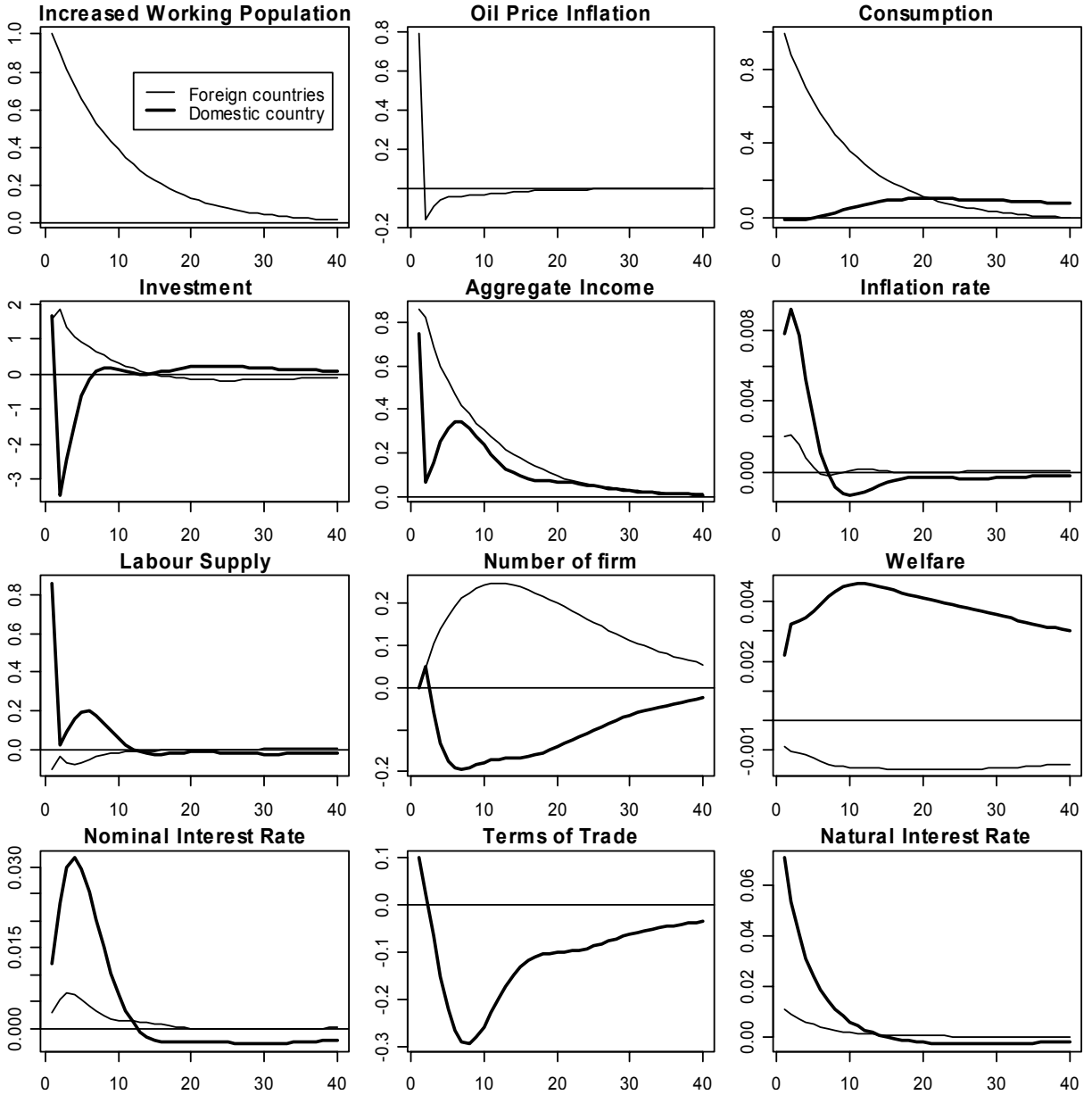
Decreased Labor Disutility

- A positive shock is given to the weight coefficient on consumption from utility in welfare function in the rest of the world


Decreased Labor Disutility
Foreign countries
Domestic country
Oil Price Inflation
Consumption
Investment
Aggregate Income
Inflation rate
Labour Supply
Number of firm
Welfare
Nominal Interest Rate
Terms of Trade
Natural Interest Rate

Increased Working Population

- Suppose that massive population shifts from rural areas to the industrial cities
- This is a unique experiment that cannot be examined in the standard dynamic general equilibrium model with fixed varieties.


Increased Working Population
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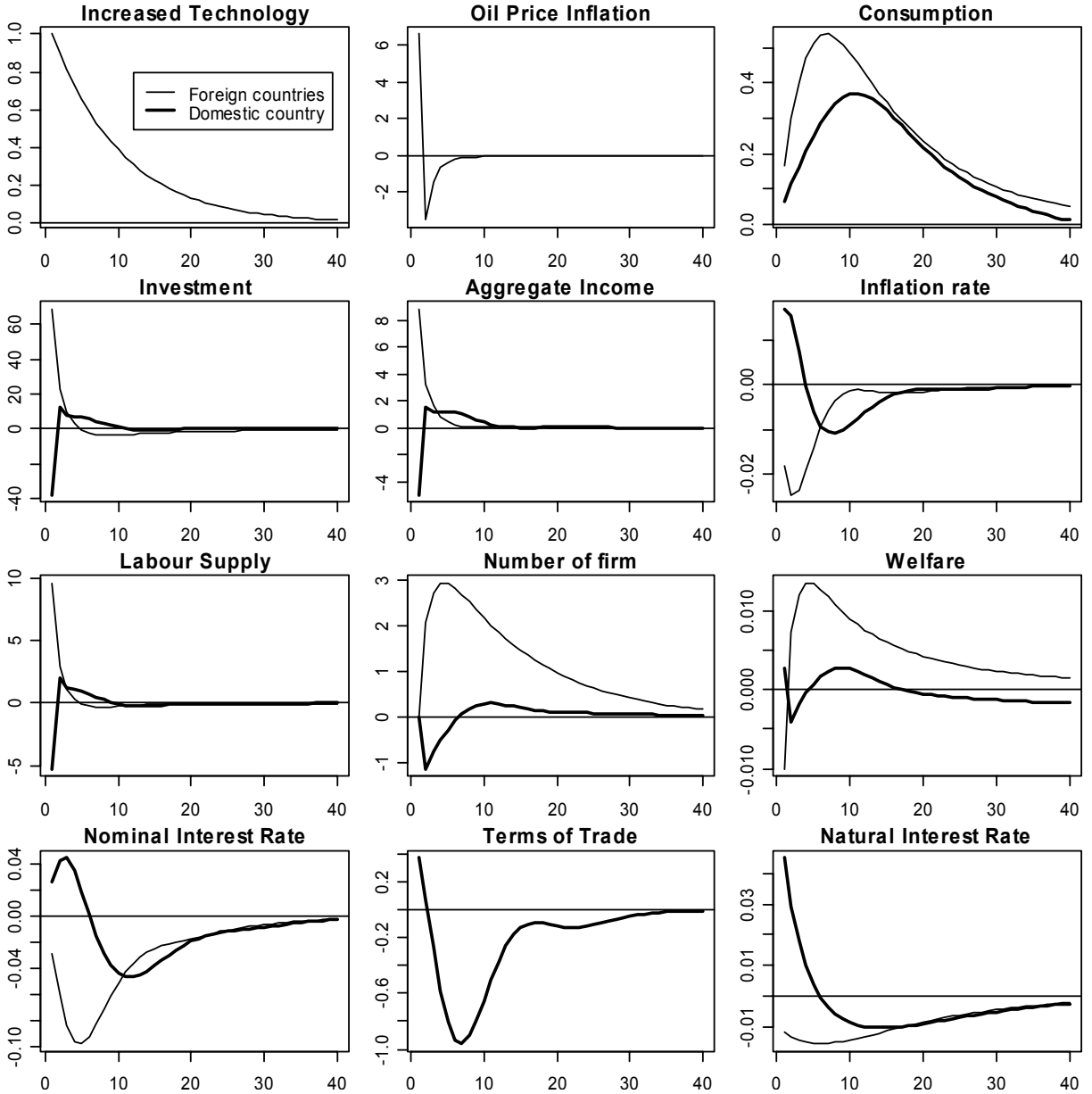
Increased Technology

- A positive shock is given to the standard technology in the rest of the world.
- This is a supply side shock in the rest of the world but considered to be a demand shock to the domestic country.


Increased Technology
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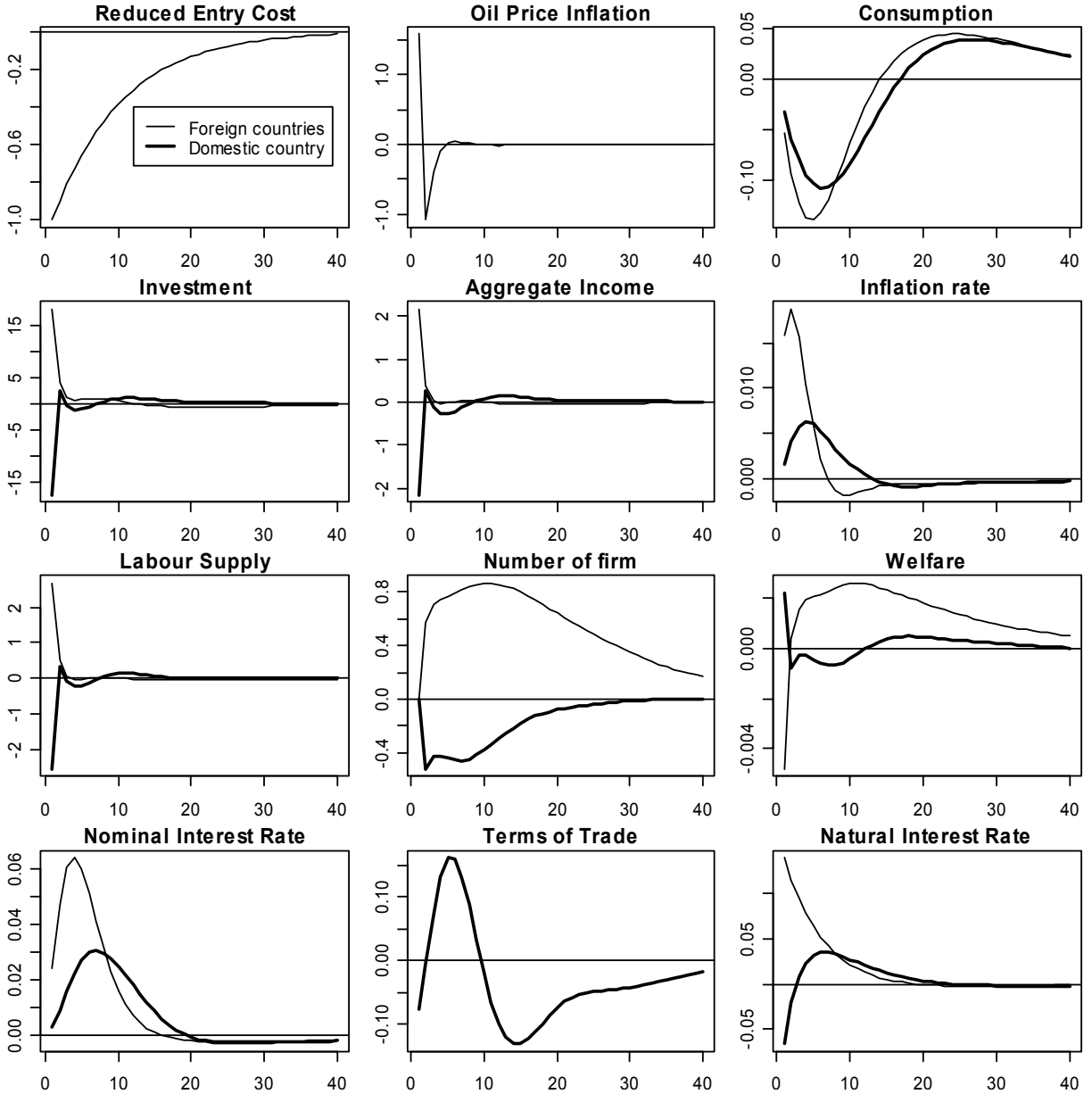
Reduced Entry Cost

- Reduced fixed cost is naturally interpreted as an improved technology since fewer goods are needed to establish a firm, namely for production.
- This is also a unique simulation to the endogenous variety model.
- Again, shock is given to the rest of the world.


Reduced Entry Cost
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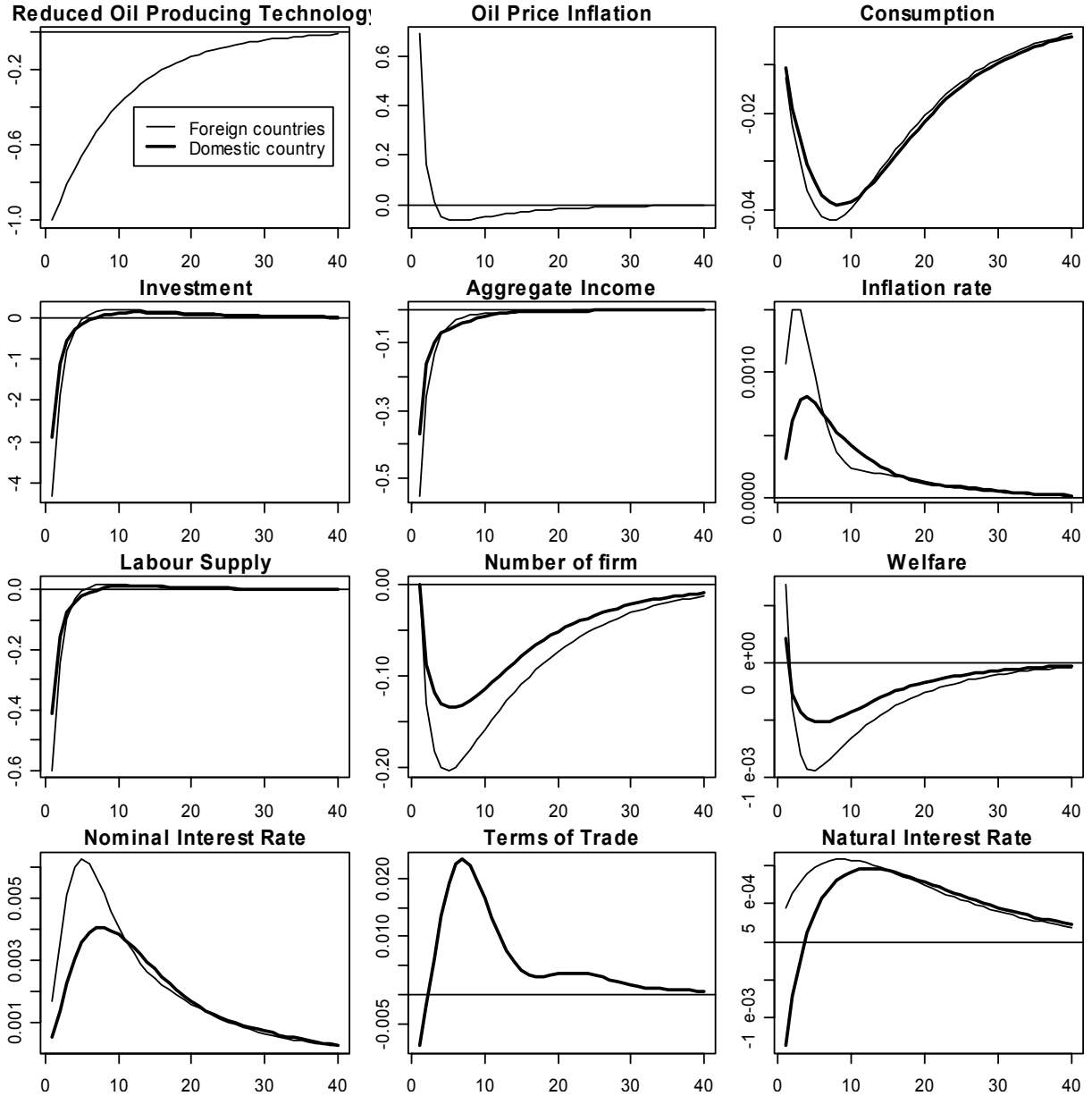
Reduced Oil-Producing Technology

- Reduced oil-producing technology is not the reality for the current soaring oil prices since no clear evidence of damaged oil plant technology has been reported.
- However, very useful to understand truly supply side effects on oil prices and the contrast between the expectation shock about future deterioration of oil production.


Reduced Oil Producing Technolog
Foreign countries
Domestic country
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Expectation Shocks

Expectation Shock

- Assume that agents expect some shock will occur after a year from now.
- Examined in Beaudry and Portier (2004) Jaimovich and Rebelo (2005) and Christiano, Motto and Rostagno (2006).
- Key is the tug of war between the substitution effect and wealth effect.

General Solution

- Linearized model (~denotes difference from steady state):

$$\alpha_0 \mathrm{E}_t \tilde{Z}_{t+1} + \alpha_1 \tilde{Z}_t + \alpha_2 \tilde{Z}_{t-1} + \beta_0 \mathrm{E}_t \tilde{S}_{t+1} + \beta_1 \tilde{S}_t = 0 \text{ and}$$

$$\tilde{S}_{\mathrm{t}} = P\tilde{S}_{t-1} + C\varepsilon_t$$

- Solutions:

$$\tilde{Z}_t = A\tilde{Z}_{t-1} + B\tilde{S}_t \text{ and } \tilde{S}_t = P\tilde{S}_{t-1} + C\varepsilon_t$$

- A and B are obtained as:

$$\alpha_0 A^2 + \alpha_1 A + \alpha_2 = 0 \text{ and}$$

$$\left(\beta_0 + \alpha_0 B\right) P + \beta_1 + \alpha_1 B + \alpha_0 AB = 0$$

Expectation Shock Process

- Assume simple shock process as

$$\tilde{s}_t = \rho \tilde{s}_{t-1} + \varepsilon_{t-p} + \xi_t$$

- In canonical form

$$\begin{pmatrix} \tilde{s}_t \\ \varepsilon_t \\ \varepsilon_{t-1} \end{pmatrix} = \begin{pmatrix} \rho & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} \tilde{s}_{t-1} \\ \varepsilon_{t-1} \\ \varepsilon_{t-2} \end{pmatrix} + \begin{pmatrix} \xi_{t-1} \\ \varepsilon_t \\ 0 \end{pmatrix}$$

- receive a news that "productivity is raised in period 2" today

$$\begin{pmatrix} \tilde{s}_0 \\ \varepsilon_0 \\ \varepsilon_{-1} \end{pmatrix} = \begin{pmatrix} \rho & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} \tilde{s}_{-1} \\ \varepsilon_{-1} \\ \varepsilon_{-2} \end{pmatrix} + \begin{pmatrix} 0 \\ \varepsilon_0 \\ 0 \end{pmatrix}$$

- Shock at period 2 expected at period 1 is

$$\mathrm{E}_0\begin{pmatrix}\tilde{s}_2\\ \varepsilon_2\\ \varepsilon_1\end{pmatrix}=\begin{pmatrix}\rho & 0 & 1\\ 0 & 0 & 0\\ 0 & 1 & 0\end{pmatrix}^2\begin{pmatrix}\tilde{s}_0\\ \varepsilon_0\\ \varepsilon_{-1}\end{pmatrix}$$

- Therefore

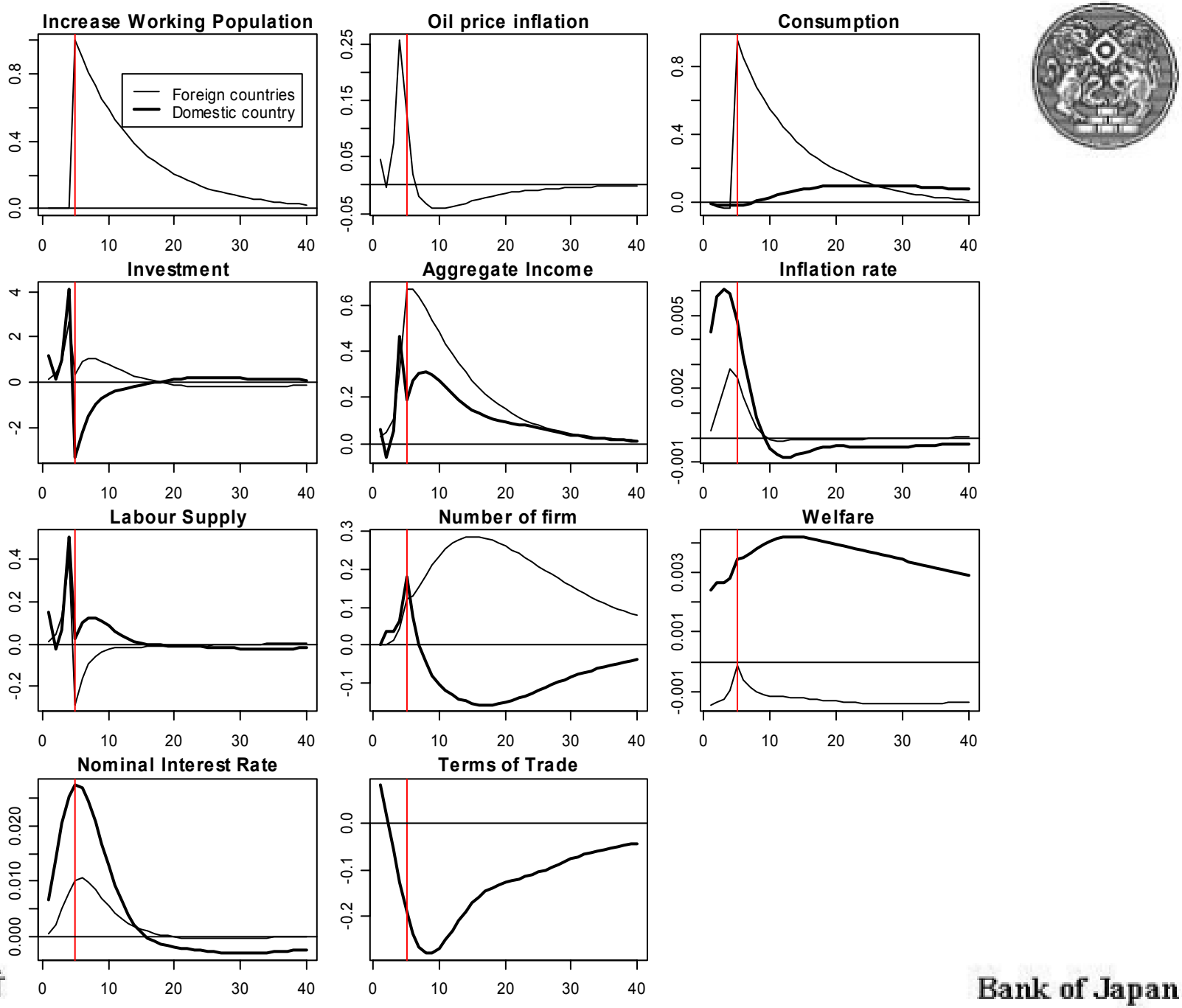
$$\mathrm{E}_0\tilde{s}_2=\varepsilon_0$$

- If this news turns out to be false at period 2,

$$\begin{pmatrix}\tilde{s}_2\\ \varepsilon_2\\ \varepsilon_1\end{pmatrix}=\begin{pmatrix}\rho & 0 & 1\\ 0 & 0 & 0\\ 0 & 1 & 0\end{pmatrix}\begin{pmatrix}\tilde{s}_1\\ \varepsilon_0\\ \varepsilon_{-1}\end{pmatrix}+\begin{pmatrix}-\varepsilon_0\\ 0\\ 0\end{pmatrix}=\begin{pmatrix}0\\ 0\\ 0\end{pmatrix}$$

Expected Increase in Working Population

- Further economic expansion in emerging economies, such as the BRIC countries, are expected.
- Some analysts have pointed out this is the reason why we are facing the current oil price hikes.
- We simulate a situation of an increase in economic activities due to increased working population next year.



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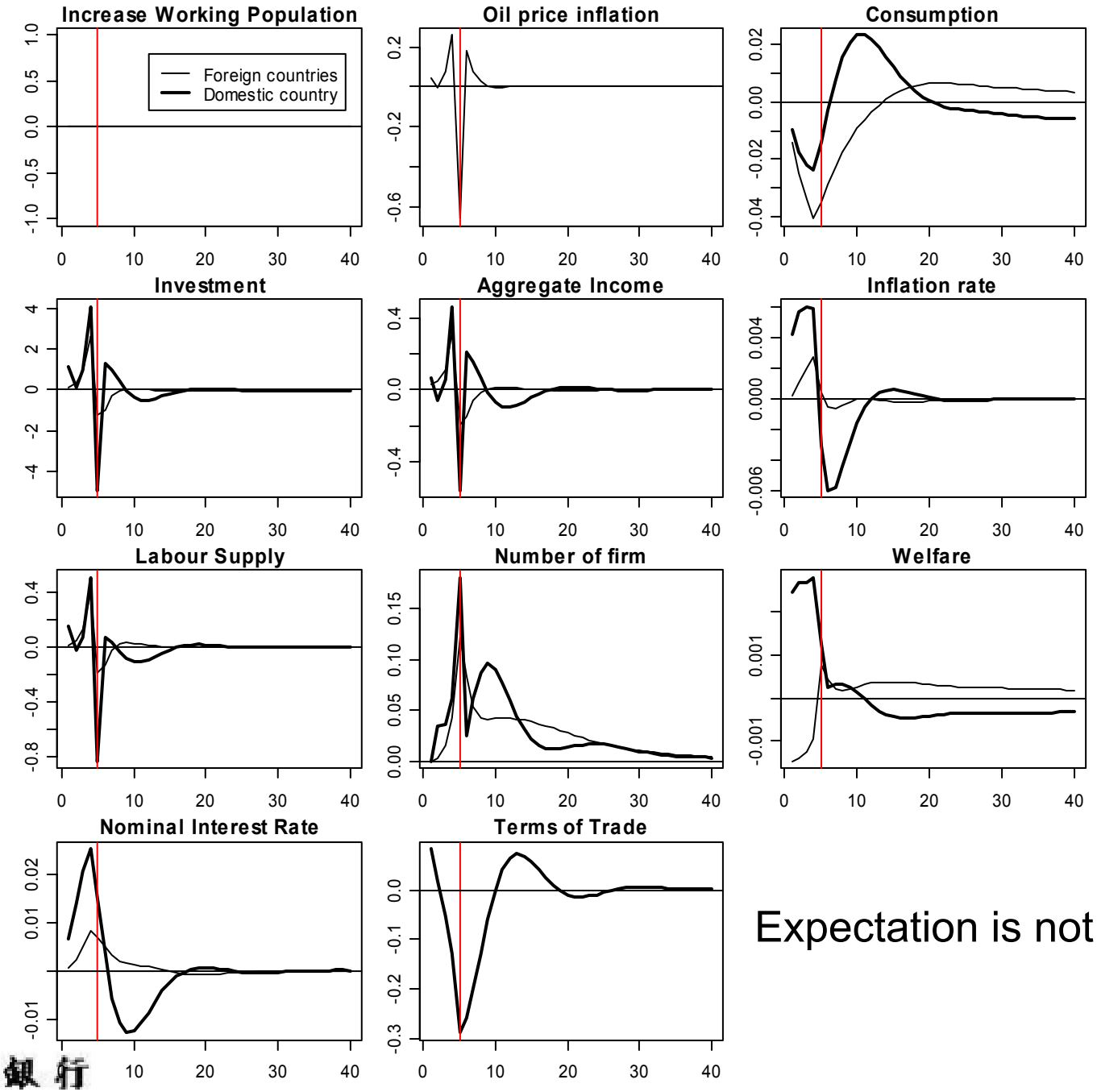
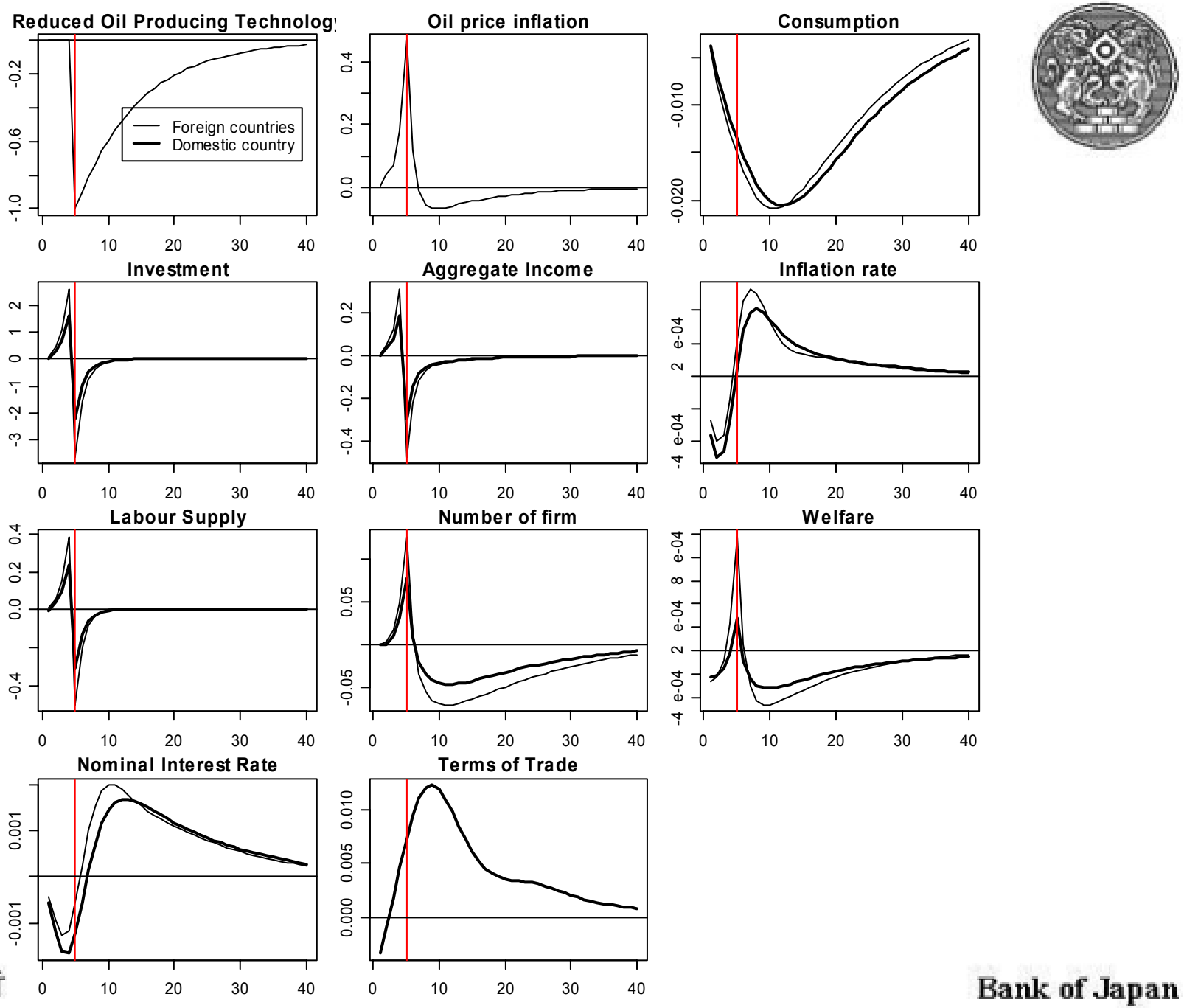


Expectation is not materialized

Expected Reduction in Oil-Producing Technology

- As documented in the OPEC statement, the biggest concerns are geopolitical developments and speculation in the oil futures markets.
- Here, we draw impulse responses when people expect that oil-producing technology is reduced by 1 per cent next year in the rest of the world.



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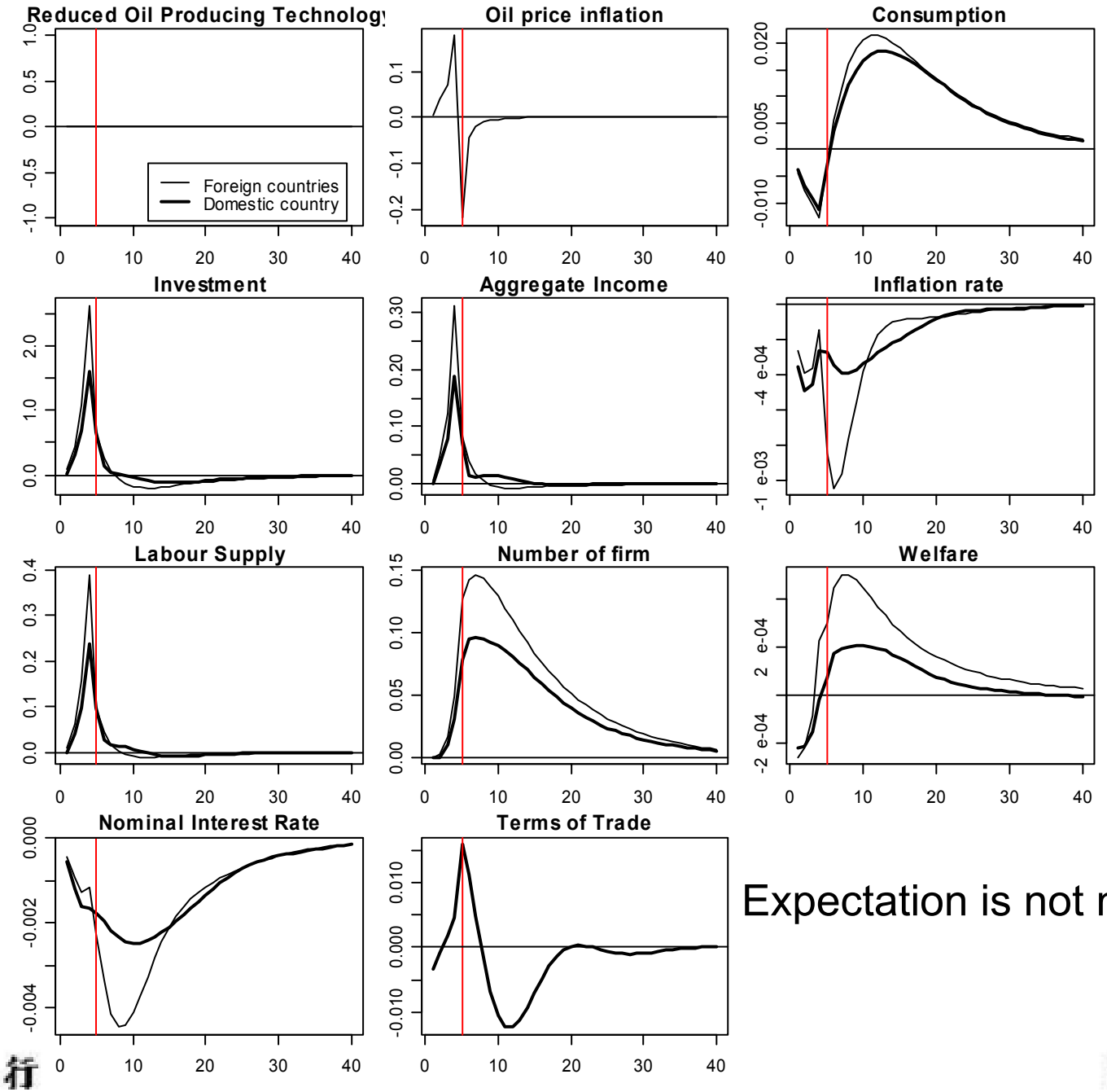


Expectation is not materialized

- Anticipation about future deteriorating oil-producing technology increases the value of oil and oil prices.
- Households increase the labor supply due to negative wealth effects and consumption is reduced gradually thanks to consumption smoothing to prepare for lower income in the future.
- Investment is increased to satisfy the resource constraint.
- Initially after the news about future lower technology on oil production is received, the labor supply curve shifts outward. This, then, reduces real wages. Therefore, aggregate inflation rates decrease all over the world.

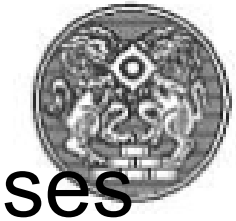
- To materialize higher inflation across the world after oil price hikes, we need very strong labor adjustment costs (possibly with human capital formation) so that the substitution effects for smoothing labor supply dominate.
- This will keep the labor supply curve from shifting outward.
- Therefore, real wage would increase

Conclusion

Conclusion

- We have examined several mechanisms which induce soaring oil prices.
- It is of great importance to acknowledge the source of economic fluctuations, including oil price developments, so that they can conduct proper stabilization policy.

- Even with similar magnitude of oil price hikes, effects on inflation, terms of trade and welfare are quite different.
- Particularly, cases with increased technology, reduced fixed cost, and increased working population are intriguing.



- With increased technology, MC decreases and π is lowered in F, while π increases due to increased EX and therefore TOT improves in D.
- With reduced fixed cost, I and π increases with increased number of firms while C decreases in F while EX decreases and TOT worsens in D.
- With increased working population, MC as well as π rise in F similar to the case with reduced fixed cost. Yet, TOT improves in D thanks to more demand for domestic goods.

- Following OPEC statement, we simulate with expectation on future increase in oil demand and anxiety for future deterioration of oil producing facility.
- Both scenarios result in soaring oil prices, but in the latter, aggregate inflation rates across the world decrease.
- We need to inquire into the role of expectation shock on soaring oil prices.