Product Variety, Firm Entry, and Terms of Trade Dynamics

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What I did in this paper

In response to a positive domestic productivity shock:

- **Standard Real Business Cycle (RBC) model:**

$$TOT = \frac{p_F}{p_H} \quad \uparrow \quad \textbf{(Depreciation)}$$

- **Empirical results** (VAR by Corsetti, et al. (2006), Enders and Müller (2009)) :

$$TOT = \frac{p_F}{p_H} \quad \downarrow \quad \textbf{(Appreciation)}$$

I explain the observed TOT dynamics driven by a productivity shock in a two-country DSGE model

How I explain TOT dynamics

A two-country DSGE model augmented with firm-specific heterogeneous productivity and non-homothetic preference

$$TOT_t \equiv \frac{\overline{p}^*_{Xt}}{\overline{p}_{Xt}} = \underbrace{\left(\frac{\frac{\tau^*_t W^*_t}{Z^*_t}}{\frac{\tau_t W_t}{Z_t}}\right)}_{\text{Relative cost of units of effective labor}} \overbrace{\left(\frac{z_{Xt}}{z^*_{Xt}}\right)}^{\text{I use this channel } \rightarrow \boxed{\text{Relative cutoff productivity}}}$$

z^*_{Xt}: cutoff productivity of foreign firms exporting to the home economy

z_{Xt}: cutoff productivity of home firms exporting to the foreign economy

Previous literature on TOT dynamics & my paper (1)

- With extensive margin but through the relative cost of effective labor:

  e.g., Ghironi and Melitz (2005) —**But they need inelastic labor supply. Their model does not induce short-run appreciation.**

  Corsetti, Martin and Pesenti (2006) —**Only in the case of reduction of market entry cost**

$$TOT_t \equiv \frac{\overline{p}^*_{Xt}}{\overline{p}_{Xt}} = \underbrace{\left(\frac{\frac{\tau^*_t W^*_t}{Z^*_t}}{\frac{\tau_t W_t}{Z_t}}\right)}_{\text{Relative cost of units of effective labor}} \overbrace{\left(\frac{z_{Xt}}{z^*_{Xt}}\right)}^{\textbf{My paper!} \longrightarrow \boxed{\text{Relative cutoff productivity}}}$$

Previous literature on TOT dynamics & my paper (2)

- Without extensive margin:
  e.g., Corsetti, Dedola and Leduc (2008), Enders and Müller (2009)
  — **assumption of incomplete asset market, low substitution elasticity, home bias, persistence of Z are needed**

My paper! $\longrightarrow$ $\boxed{\text{Relative cutoff productivity}}$

$$TOT_t \equiv \frac{\overline{p}^*_{Xt}}{\overline{p}_{Xt}} = \underbrace{\left(\frac{\frac{\tau^*_t W^*_t}{Z^*_t}}{\frac{\tau_t W_t}{Z_t}}\right)}_{\text{Relative cost of units of effective labor}} \overbrace{\left(\frac{z_{Xt}}{z^*_{Xt}}\right)}$$

My contribution

1. I account for TOT dynamics **through the channel of relative cutoff firm-specific productivity**.

   $\longrightarrow$ This resolution does not resort to inelastic labor supply, persistence of productivity, home bias, or elasticity of substitution

2. **I find that asset market openness plays a key role to explain the dynamics of the terms of trade through the channel of relative cutoff productivity.**

Quick intuition (1): Two competing effects

- If there is a positive productivity shock in the Home country,
  - **Income effect**: Income goes up — households like more goods varieties $\longrightarrow$ Even less productive foreign firms can export to Home country ($z_X^* \downarrow$) $\longrightarrow$ **Depreciates TOT**

Quick intuition (1): Two competing effects

- If there is a positive productivity shock in the Home country,
  - **Income effect**: Income goes up — households like more goods varieties $\longrightarrow$ Even less productive foreign firms can export to Home country ($z_X^* \downarrow$) $\longrightarrow$ **Depreciates TOT**
  - **Markup effect**: More Home firms in the market$\longrightarrow$ markup goes down and only relatively productive foreign firms can enter the domestic market. ($z_X^* \uparrow$) $\longrightarrow$ **Appreciates TOT**

Relative importance of these two effects differ across different asset market assumptions.

Quick intuition (2): The role of the asset market

financial autarky	**incomplete market**	**complete market**
Relative income change is big, relative change of demand at home is big	partial international risk sharing, relative change of demand is mitigated	perfect risk sharing
Income effect > Markup effect	Markup effect > Income effect	Markup effect > > Income effect
$z_{Xt}\downarrow$, $z^*_{Xt}\downarrow\downarrow$	$z_{Xt}\downarrow\downarrow$, $z^*_{Xt}\downarrow$	$z_{Xt}\downarrow\downarrow$,$z^*_{Xt}\uparrow$
$\frac{z_{Xt}}{z^*_{Xt}}\uparrow$	$\frac{z_{Xt}}{z^*_{Xt}}\downarrow$	$\frac{z_{Xt}}{z^*_{Xt}}\downarrow\downarrow$
TOT depreciation	**TOT appreciation**	**more TOT appreciation**

Empirical evidence: VAR & MFEV identification

- Maximum Forecast-Error Variance identification following Uhlig (2004), Francis, Owyang and Roush (2007), Sims (2009), Barsky and Sims (2010):

  Basic idea: To extract the exogenous shocks that explain the forecast error variance of productivity as much as possible

  – Reduced VAR: $y_t = B(L)u_t$, Structural: $y_t = C(L)\varepsilon_t$

  – Mapping between reduced & structural errors :$u_t = A_0\varepsilon_t$

  – VCV of u_t: $\Sigma = A_0 A_0'$

  – Impulse response function: $B(L)A_0$

  – Forecast error (h-period ahead): $y_{t+h} - E_{t-1}y_{t+h} = \sum_{i=0}^{h} B_i A_0 \varepsilon_{t+h-i}$

  $\longrightarrow$ Share of h-period ahead forecast error variance of variable j due to shock k:

$$\omega_{jk}(\alpha(h)) = \frac{\sum_{i=0}^{h} B_{j,i}\alpha\alpha' B_{j,i}'}{\sum_{i=0}^{h} B_{j,i}\Sigma B_{j,i}'}$$

  where α is the k-th column of A_0

MFEV identification (cont'd)

Basic idea of MFEV identification:
Choose α that explains the share of forecast error variance of productivity as much as possible for over h periods

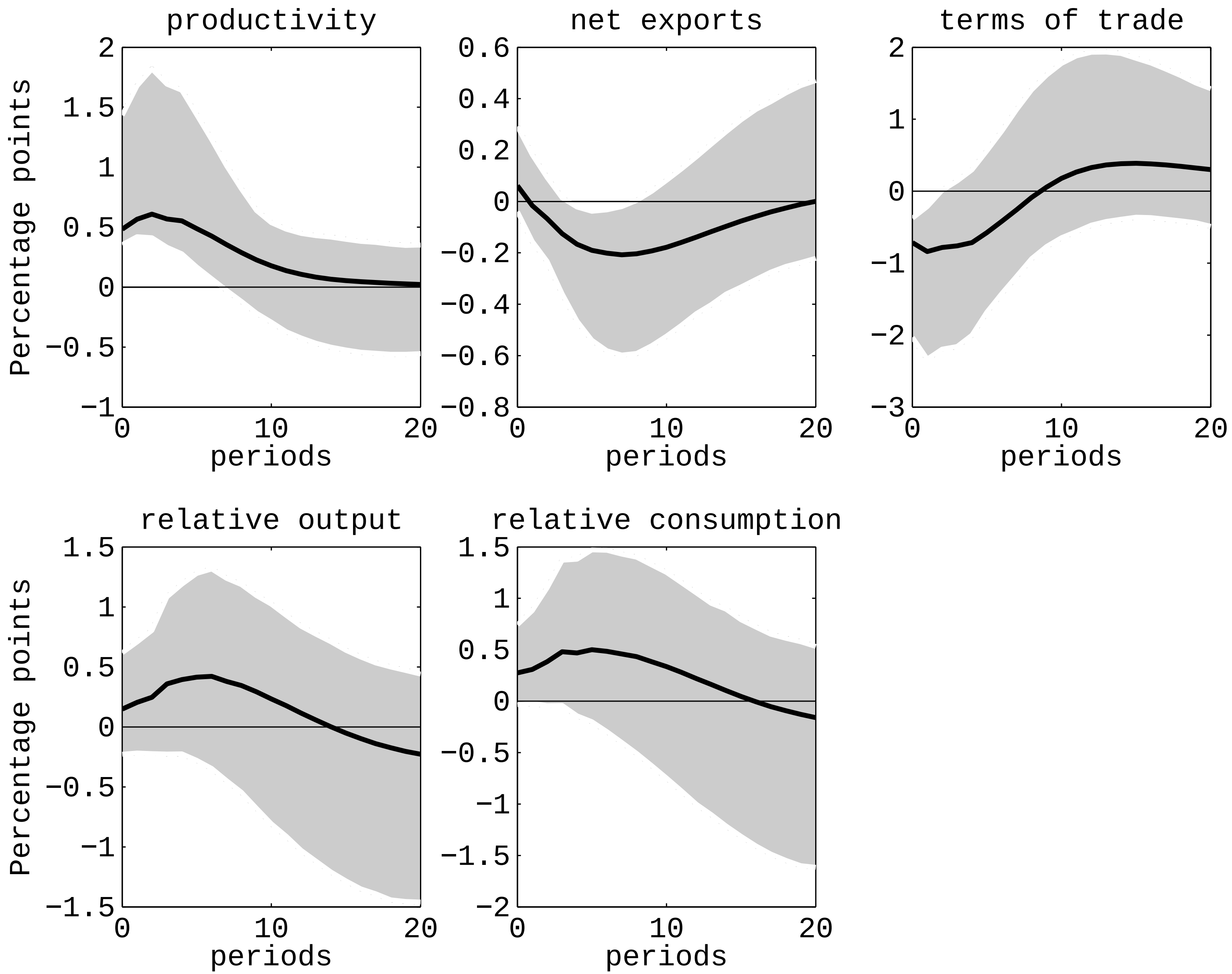
$$\max \omega_{11}(\alpha(h)),$$

subject to

$$\alpha'\alpha = 1 \;\; \text{(for errors to have unit variance)}$$

Data: US labor productivity, net exports, terms of trade, US output and consumption relative to the aggregate of other G7 countries
Sample: From 1973 to 2010, quarterly

Impulse responses to a 1% technology shock



Brief overview of the model

- Two-country DSGE model with heterogeneous firm-specific productivity as in Ghironi and Melitz (2005)

- Non-homothetic preference as in Melitz and Ottaviano (2008): Mechanic to induce endogenous markup

- I consider three asset market structures:

1. Financial autarky

2. Incomplete market

3. Complete market

Model: Household's preference

A representative household maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, 1 - H_t\right)$$

Following Melitz and Ottaviano (2008),

$$C_t = \omega \int_{i \in \Omega} q_{it} di - \frac{1}{2}\gamma \int_{i \in \Omega} \left(q_{it}\right)^2 di - \frac{1}{2}\eta \left(\int_{i \in \Omega} q_{it} di\right)^2$$

q_{it}: The amount of consumption of each variety i.

Ω: Possibly-consumed set of goods

γ: The index of the degree of product differentiation between varieties. As long as $\gamma > 0$, this preference exhibits **love of variety**.

η: The pattern of substitution. Large η means closer substitution between varieties.

Model: Household's preference

- Demand function for each variety:

$$q_t(i) = \frac{1}{\gamma}\left(\omega - \frac{1}{\lambda_t}p_t(i) - \eta Q_t\right)$$

where $Q_t \equiv \int_{i\in\Omega} q_{it}di$ and λ_t is the Lagrangian multiplier of the expenditure minimization problem.

- The maximum price the firm can set (zero demand):

$$\hat{p}_t = \frac{\omega\gamma\lambda_t + \eta N_t \bar{p}_t}{\gamma + \eta N_t}$$

where N_t is the number of the goods varieties consumed and $\bar{p}_t$ is the average price in the market.

Model: Firms — overview

- A continuum of firms which produce different varieties $i \in \Omega$
- Production requires labor only
- Prior to entry, firms are identical. They face sunk cost, f_E effective labor units $(= \frac{W_t f_{Et}}{Z_t})$. After they enter the market, firm-specific productivity, z is revealed.

  I assume Pareto distribution for z: $G(z) = 1 - \left(\frac{z_{min}}{z}\right)^{\theta}$ with support $[z_{min}, \infty)$
- Firms also face aggregate labor productivity, Z_t. Therefore, $Z_t z$ units of output are produced per one unit of labor.
- Firms produce until they face a death shock, which occurs with probability δ every period.

Model: Firms serving domestic sales

Each firm with z serving in the domestic market maximizes:

$$\pi_{Dt}(z) = p_{Dt}(z)q_{Dt}(z) - MC_t(z)q_{Dt}(z)$$

subject to the demand function:

$$q_{Dt}(z) = \frac{1}{\gamma}\left(\omega - \frac{1}{\lambda_t}p_{Dt}(z) - \eta N_t \bar{q}_t\right)$$

I obtain the optimal price:

$$p_{Dt}(z) = \frac{1}{2}MC_t(z) + \frac{1}{2}MC_t(z_{Dt}) = \frac{1}{2}\frac{W_t}{Z_t z} + \frac{1}{2}\frac{W_t}{Z_t z_{Dt}}$$

where z_{Dt} is **the cutoff productivity of firms for positive sale in domestic market**.

Model: Firms serving export sales

Each firm with z serving export sales maximizes:

$$\pi_{Xt}(z) = p_{Xt}(z)q_{Xt}(z) - \tau_t MC_t(z)q_{Xt}(z)$$

subject to the demand function

$$q_{Xt}(z) = \frac{1}{\gamma}\left(\omega - \frac{1}{\lambda_t^*}p_{Xt}(z) - \eta N_t^* \bar{q}_t^*\right)$$

I obtain the optimal price:

$$p_{Xt}(z) = \frac{1}{2}\tau_t MC_t(z) + \frac{1}{2}\tau_t MC_t(z_{Xt}) = \frac{1}{2}\frac{W_t}{Z_t z} + \frac{\tau_t}{2}\frac{W_t}{Z_t z_{Xt}}$$

where z_{Xt} is **the cutoff productivity for positive sales in export (foreign) market**.

The cutoff productivity

The firm with cutoff productivity, z_{Dt}, must satisfy

$$\frac{\omega\gamma\lambda_t + \eta N_t \bar{p}_t}{\gamma + \eta N_t} = \frac{W_t}{Z_t z_{Dt}}$$

where N_t is the total number of firms selling in Home economy.

Similarly, the cutoff productivity, z_{Xt}, must satisfy

$$\frac{\omega\gamma\lambda_t^* + \eta N_t^* \bar{p}_t^*}{\gamma + \eta N_t^*} = \tau_t \frac{W_t}{Z_t z_{Xt}}$$

where N_t^* is the total number of firms selling in Foreign economy.

Firm averages

Given the distribution of z, $G(z)$, the average prices are:

$$\overline{p}_{Dt} = \frac{2\theta+1}{2(\theta+1)}\frac{W_t}{Z_t z_{Dt}}, \quad \overline{p}_{Xt} = \frac{2\theta+1}{2(\theta+1)}\tau_t\frac{W_t}{Z_t z_{Xt}}$$

Terms of trade

$$TOT_t \equiv \frac{\overline{p}^*_{Xt}}{\overline{p}_{Xt}} = \underbrace{\left(\frac{\frac{\tau_t^* W_t^*}{Z_t^*}}{\frac{\tau_t W_t}{Z_t}}\right)}_{\text{Relative cost of units of effective labor}} \overbrace{\left(\frac{z_{Xt}}{z^*_{Xt}}\right)}^{\text{Relative cutoff productivity}}$$

Free entry condition

Present discounted value of the stream of expected profits:

$$v_t = E_t \sum_{s=t}^{\infty} [\beta(1-\delta)]^{s-t} \frac{U_c(C_{t+s}, 1-H_{t+s})}{U_c(C_t, 1-H_t)} \pi_s$$

where δ is the exogenous death rate of the firm and π_t is one-period expected profit of the firm and $\pi_t = \pi_{Dt} + \pi_{Xt}$.

Free entry condition:

$$v_t = \frac{W_t f_{Et}}{Z_t}$$

Number of firms

Recall:

- Distribution of z: $G(z) \equiv 1 - \left(\frac{z_{min}}{z}\right)^{\theta}$
- Number of firms possibly producing: $N_p = (1-\delta)N_{pt-1} + N_{Et}$, where N_{Et} is the number of entrants

$$N_{Dt} = N_{pt}\left(\frac{z_{min}}{z_{Dt}}\right)^{\theta}$$

$$N_{Xt} = N_{pt}\left(\frac{z_{min}}{z_{Xt}}\right)^{\theta}$$

Asset market structures: (1) Financial autarky

In this case, the household's income is perfectly equal to its output.

The value of exports equal to the value of imports. (Balanced trade):

$$
\begin{aligned}
& N_{Xt} \frac{1}{1-G(z_{Xt})} \int_{z_{Xt}}^{\infty} p_{Xt}(z) q_{Xt}(z) dG(z) \\
= & N^*_{Xt} \frac{1}{1-G(z^*_{Xt})} \int_{z^*_{Xt}}^{\infty} p^*_{Xt}(z) q^*_{Xt}(z) dG(z)
\end{aligned}
$$

Asset market structures: (2) Incomplete market

The household trades home bonds and foreign bonds. There are costs of adjusting holdings of home and foreign bonds.

In this case, the budget constraint of the household can be rewritten as:

$$P_t^c B_{t+1} + P_t^{c*} B_{*t+1} + P_t^c \frac{\upsilon}{2} \left(B_{t+1}\right)^2 + P_t^{c*} \frac{\upsilon}{2} \left(B_{*t+1}\right)^2 + P_t^c C_t + N_{pt} v_t$$
$$= (1 + r_t) P_t^c B_t + (1 + r_t^*) P_t^{c*} B_{*t} + T_t + W_t H_t + N_{p,t-1}(1 - \delta)(\pi_t + v_t)$$

Asset market structures: (3) Complete market

Household's period budget constraint can be written as follows:

$$P_t^c C_t + \sum_{s_{t+1}} Q_t(s^t, s_{t+1}) B_{t+1}(s^t, s_{t+1}) + N_{pt} v_t$$
$$= W_t H_t + B_t(s^t) + N_{pt-1}(1-\delta)(\pi_t + v_t)$$

where $Q_t(s^t, s_{t+1})$ is the stochastic discount factor to price the state-contingent security, B_{t+1}. v_t is the post-entry average value of firm. The household trades a complete set of state-contingent securities. International risk sharing condition holds:

$$RER_t = \frac{U_{C^*t}}{U_{Ct}}$$

Perfect risk sharing among countries.

Calibration

- Functional form of utility function: Cobb-Douglas

$$u(C_t, 1 - H_t) = \frac{\left(C_t^{\kappa} (1 - H_t)^{1-\kappa}\right)^{1-\sigma}}{1 - \sigma}$$

- Shock process of productivity:

$$\begin{bmatrix} Z_t \\ Z_t^* \end{bmatrix} = \begin{bmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{bmatrix} \begin{bmatrix} Z_{t-1} \\ Z_{t-1}^* \end{bmatrix} + \begin{bmatrix} \xi_t \\ \xi_t^* \end{bmatrix}$$

- $\beta = 0.99$ (discount factor)
- $\delta = 0.025$ (death shock probability)
- $\omega = 10, \gamma = 0.5, \eta = 1, \sigma = 2$ (preference parameters)
- $\tau = 1.73$ (iceberg trade cost)
- $f_E = 0.1$ (fixed entry cost)
- $\theta = 3.4$ (Pareto shape parameter)
- $\phi_Z = \phi_{Z^*} = 0.906$, $\phi_{ZZ^*} = \phi_{Z^*Z} = 0.088$.

Intuitions: (1) Financial autarky (Responses to a 1% increase in Home Z)

$$TOT_t \equiv \frac{\overline{p}^*_{Xt}}{\overline{p}_{Xt}} = \underbrace{\left(\frac{\frac{\tau^*_t W^*_t}{Z^*_t}}{\frac{\tau_t W_t}{Z_t}} \right)}_{\text{Relative cost of effective labor}} \overbrace{\left(\frac{z_{Xt}}{z^*_{Xt}} \right)}^{\text{Relative cutoff productivity}}$$

Income effect $>$ markup effect

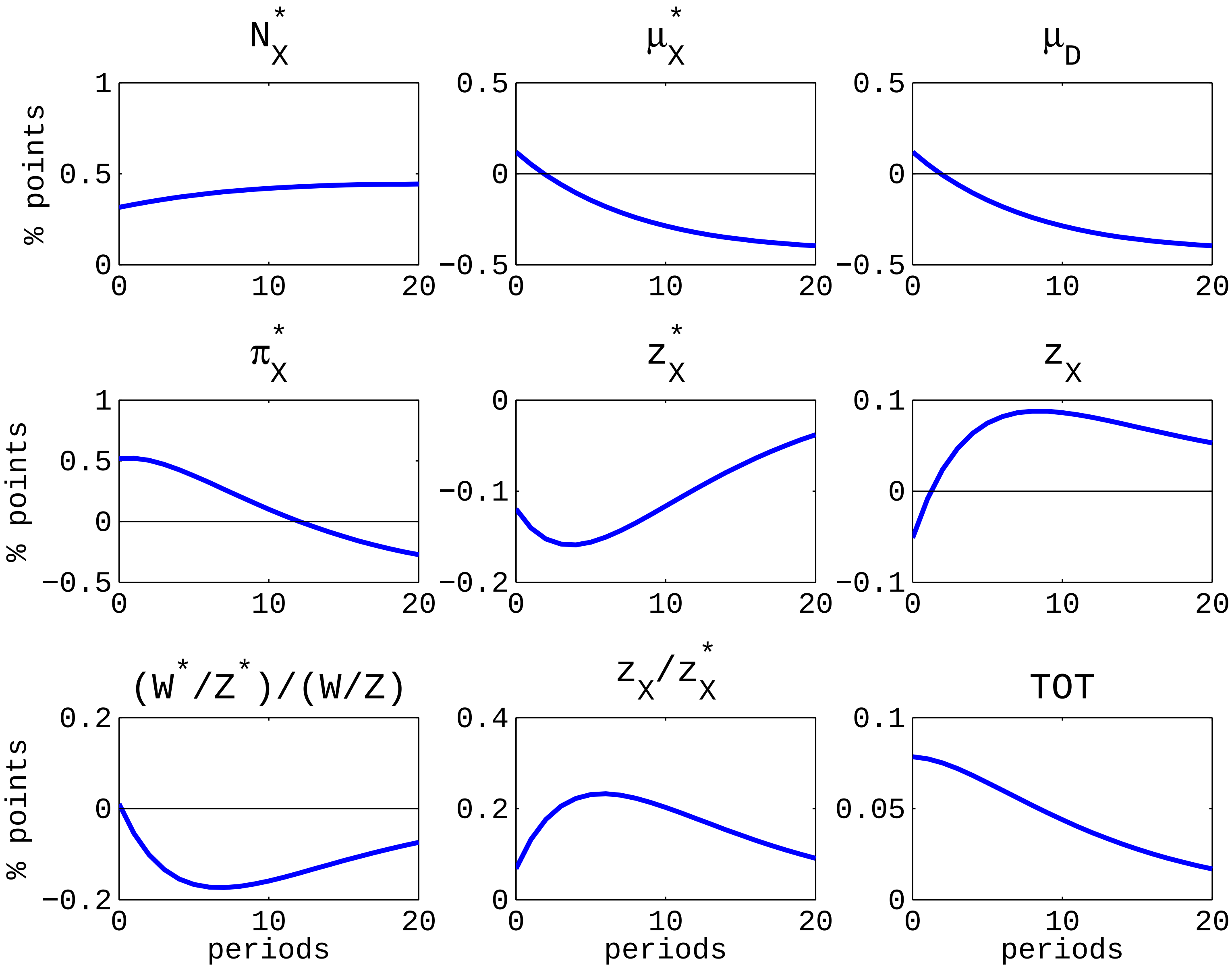
A positive productivity shock increases Home income (wealth) relative to Foreign

$\rightarrow$ This increases domestic absorption relative to foreign

$\rightarrow$ Even less productive Foreign firms export to Home economy ($z^*_X \downarrow$)

$\rightarrow$ $\frac{z_{Xt}}{z^*_{Xt}} \uparrow$ and TOT $\uparrow$ (**TOT depreciation**)

Results: (1) Financial autarky (Responses to a 1% increase in Home Z)



Intuitions: (2) Incomplete market (Responses to a 1% increase in Home Z)

$$TOT_t \equiv \frac{\overline{p}^*_{Xt}}{\overline{p}_{Xt}} = \underbrace{\left(\frac{\frac{\tau^*_t W^*_t}{Z^*_t}}{\frac{\tau_t W_t}{Z_t}}\right)}_{\text{Relative cost of units of effective labor }\uparrow} \overbrace{\left(\frac{z_{Xt}}{z^*_{Xt}}\right)}^{\text{Relative cutoff productivity }\Downarrow}$$

Income effect $<$ Markup effect

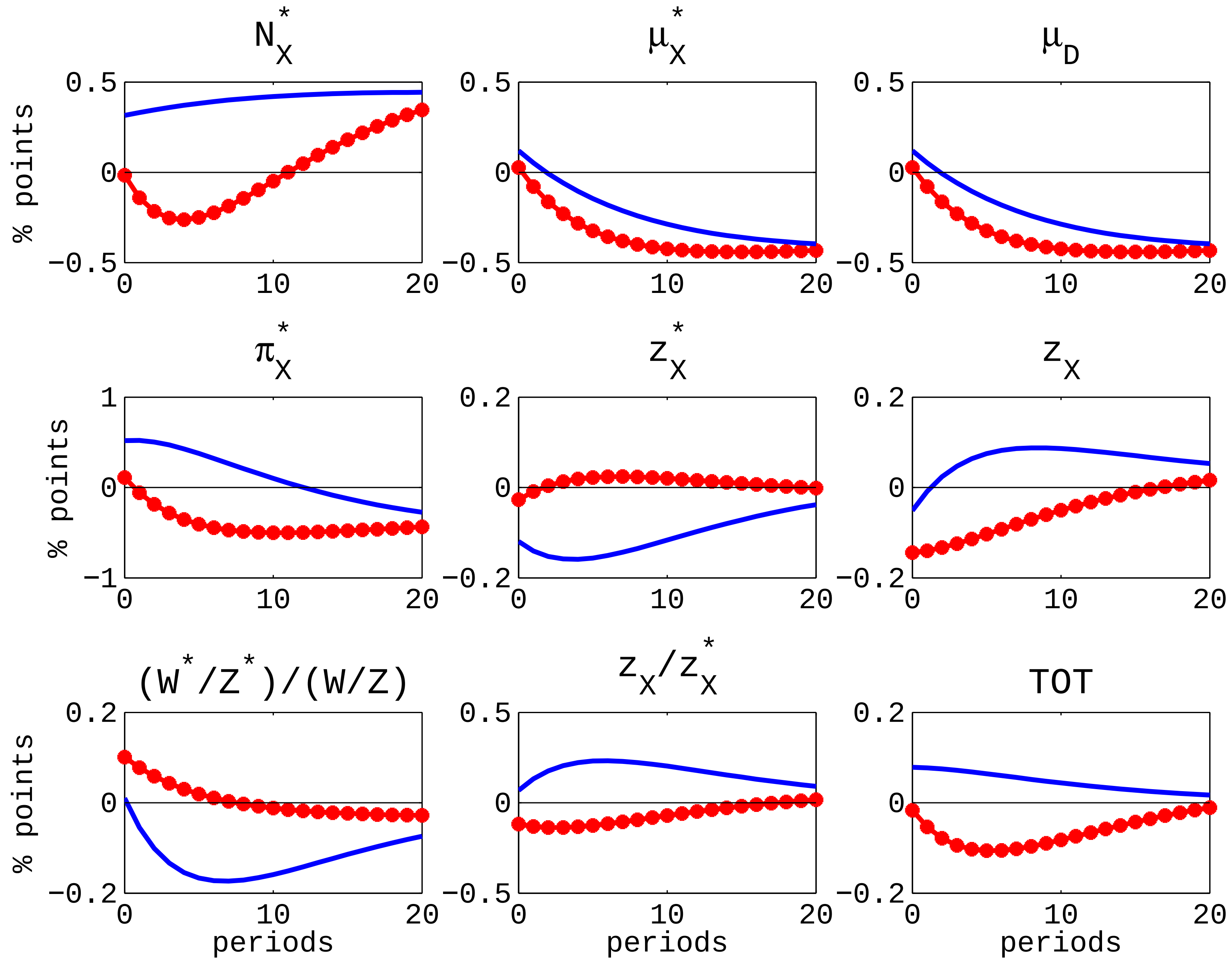
There is some degree of international risk sharing through trading bonds

$\rightarrow$ relative change of demand across countries: mitigated

- Only more productive firms can enter Home market since they need to decrease their markups and suffer from lower profits
- $z^*_{Xt} \downarrow$ but less so compared to the case of financial autarky

$\longrightarrow \frac{z_{Xt}}{z^*_{Xt}} \downarrow$ and TOT $\downarrow$ (**TOT appreciation**)

Results: (2) Incomplete market (BLUE: Autarky Red with dots: Incomplete market)



Intuitions: (3) Complete market (Responses to a 1% increase in Home Z)

$$TOT_t \equiv \frac{\overline{p}^*_{Xt}}{\overline{p}_{Xt}} = \underbrace{\left(\frac{\frac{\tau_t^* W_t^*}{Z_t^*}}{\frac{\tau_t W_t}{Z_t}} \right)}_{\text{Relative cost of units of effective labor } \uparrow} \overbrace{\left(\frac{z_{Xt}}{z^*_{Xt}} \right)}^{\text{Relative cutoff productivity } \Downarrow}$$

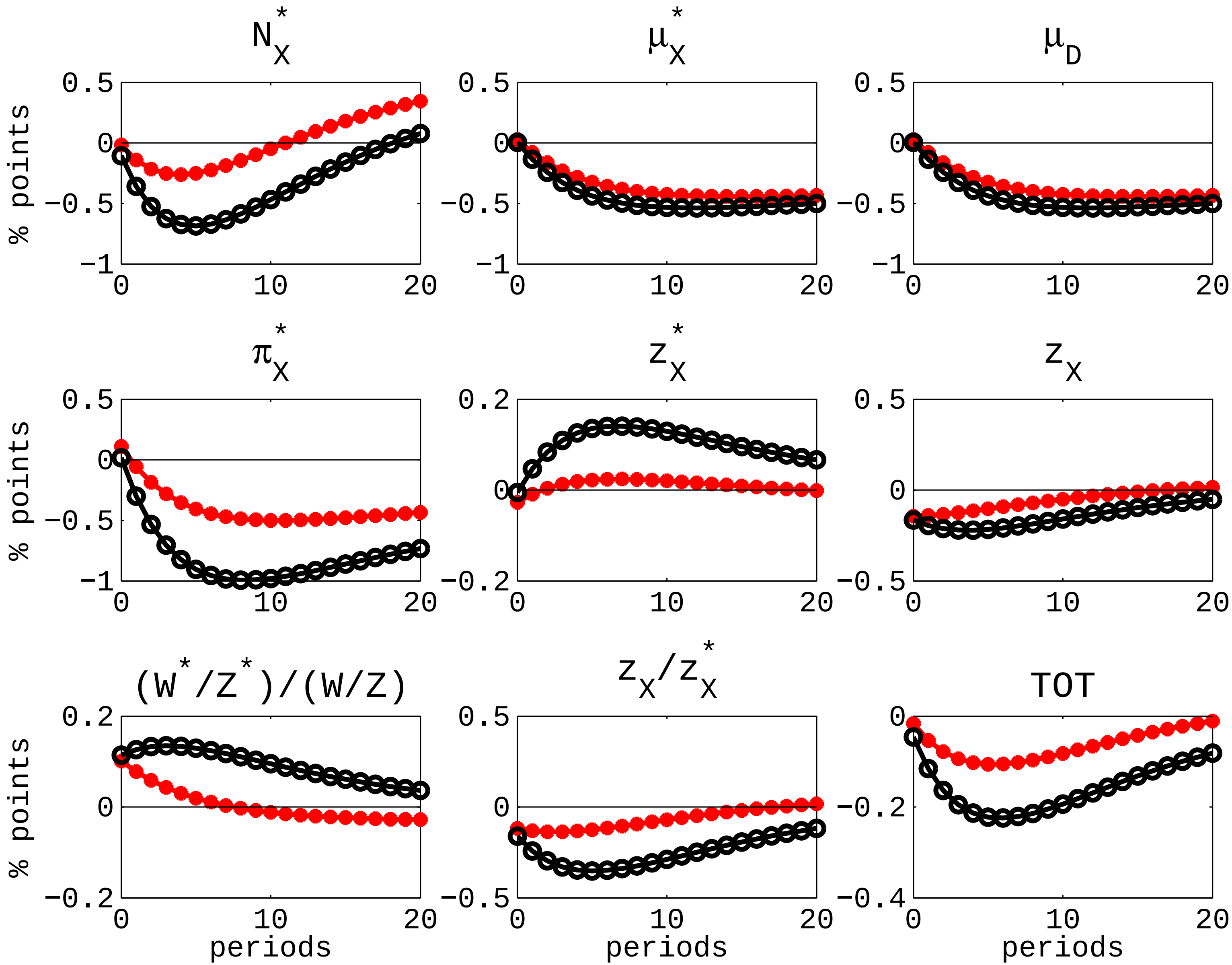
Income effect $<<$ **Markup effect**

There is perfect international risk sharing

- Only more productive firms can enter Home market since they need to decrease their markups and suffer from lower profits (z^*_X increases)

$\longrightarrow \frac{z_{Xt}}{z^*_{Xt}} \downarrow$ and TOT $\downarrow$ (**TOT appreciation**)

Results: (3) Complete market (Red with dots: Incomplete, Black with circles: Complete market)



Comparison of TOT responses (Data & Model)

I feed the process of US productivity obtained from the VAR estimation.

Periods	TOT response from data VAR	TOT response from the model
4	-0.77	-0.40
8	-0.63	-0.33
12	-0.38	-0.29
16	-0.19	-0.26

The model could account for the appreciation of the TOT observed in the data.

Conclusion

- Using a two-country DSGE model augmented with non-homothetic preference, I studied the dynamics of terms of trade. I studied
  - Case 1: Financial autarky
  - Case 2: Incomplete market
  - Case 3: Complete market

  I found that there are **two** effects on terms of trade:

  1. Income effect
  2. Markup effect

  If the risk sharing between countries are high, markup effect dominates and this causes the appreciation of the terms of trade, which is in line with the empirical results.

Future research

- Explore the TOT dynamics in emerging market countries where the financial openness plays a key role
- Explore the ability of the model to explain the volatilities and international co-movements of macroeconomic variables
- Empirically test the change of the distribution of firm-specific productivities using a large set of panel data in response to an aggregate productivity shock