Uncertainty in Global Sourcing

Learning, sequential offshoring, and selection patterns

Leandro Navarro

Johannes Gutenberg University Mainz

IIEP Baires - Seminario de Investigación

09/2019

Motivation

- Intermediate inputs explain a substantial share of global trade.
- Multinational firms have a growing role in the organization of trade and the configuration of global production networks.
- Infrastructure and institutional conditions seem to have an important influence on global sourcing decisions.
- BUT, firms usually take sourcing decision under uncertainty
  $\Rightarrow$ Vague knowledge about the existing infrastructure and institutions, particularly abroad.

Research question and main results

Main research question

- How does the uncertainty about the prevailing conditions abroad affect the global sourcing decisions of multinational firms?
- How is the allocation of offshoring across countries affected?

Main results

- Offshoring equilibrium path under uncertainty shows
  - a sequential offshoring: offshoring increases progressively over time, led by most productive firms.
  - a selection pattern in countries: preference for offshoring in certain countries driven by informational spillovers.
    $\Rightarrow$ *revealed comparative advantages*.

Literature Review

- **On heterogeneous firms, trade and global sourcing**
  Melitz (2003), Antrás and Helpman (2004, 2008).

- **On uncertainty, trade, global sourcing**
  Rob and Vettas (2003), Segura-Cayuela and Vilarrubia (2008), Albornoz et al (2012), Nguyen (2012),Ramondo et al (2013), Aeberhardt et al (2014), Handley (2014), Araujo et al (2016), Carballo (2016), Kohler et al (2018).

- **On Markov processes, Statistical decisions, Informational externalities, Bayesian learning**
  Stokey and Lucas (1989), Rob (1991), DeGroot (2005), Segura-Cayuela and Vilarrubia (2008), Sutton and Barto (2018).

- **On comparative advantages**
  Acemoglu et al (2007), Cotinot (2008).

Overview of the presentation

- **2 countries model: North - South**
    - Perfect information (PI).
    - Uncertainty in fixed cost of production in South.
- **3 countries model: North-East-South**
    - Perfect information (PI).
    - Uncertainty in fixed cost of production in foreign countries.
- **Extensions and Conclusions**

Final goods (tradable in world market)

$$U_t = \gamma_0 \ln q_{0,t} + (1-\gamma_0) \ln Q_t \quad , \quad 0 < \gamma_0 < 1$$

- $q_{0,t}$: homogeneous good's consumption in t.
- Q_t: Per-period aggregate consumption in differentiated sector (CES function):

$$Q_t = \left[\int_{i \in I_t} q_t(i)^{\alpha} di \right]^{1/\alpha} \quad , \quad 0 < \alpha < 1$$

  $q_t(i)$ refers to variety's i consumption in t, and $\sigma = \frac{1}{1-\alpha} > 1$ is the elasticity of substitution.
- Monopolistic competition in final-good (differentiated sector).

- One factor: Labor (ℓ). Labor supply: L^l, with $l = \{N, S\}$.
- Homogeneous good tecnology: $q_0 = A_{0,l}\ell_0$; with $A_{0,N} > A_{0,S}$

Differentiated sector

- Variety i's production function (in North):

$$q_t(i) = \theta \left(\frac{x_{h,t}(i)}{\eta} \right)^{\eta} \left(\frac{x_{m,t}(i)}{1-\eta} \right)^{1-\eta} \quad ; \quad 0 < \eta < 1$$

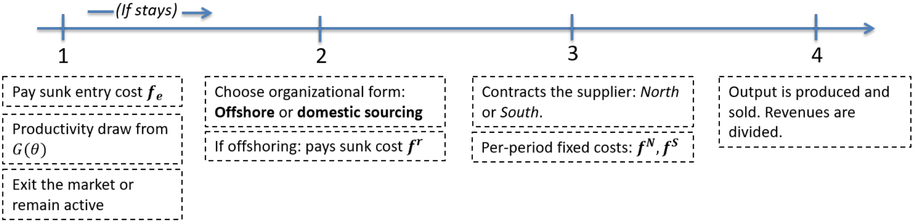
  - $x_{h,t}$: HQ services, supplied by the headquarter H.
  - $x_{m,t}$: intermediate input, supplied by the supplier M in North or South.

- Heterogeneous firms: Productivity drawn from c.d.f. $G(\theta)$.
- Both inputs are produced with constant return technologies.

Perfect information model (AH2004)

Organizational choices: Domestic sourcing *(North)* vs. Offshoring *(South)*

Timing of events



- f_e: market entry sunk cost
- f^r: offshoring sunk cost (e.g.: *market research / feasibility studies*)
- f^N, f^S: per-period fixed costs in North and South, respectively.

Assumption: Per-period fixed costs ranking App.: Assumption

$$f^N < f^S$$

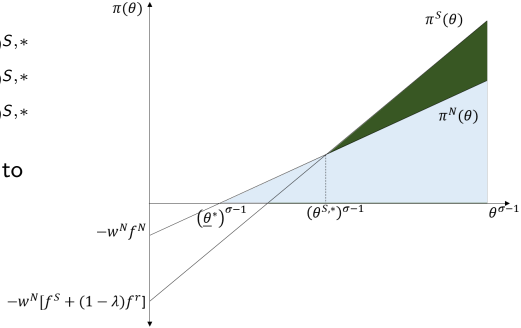
Offshoring profit premium (per-period) App.: Profit

$$\pi^{S,prem}(\theta) \equiv \pi^{S}(\theta) - \pi^{N}(\theta)$$

Offshoring cutoff, $\theta^{S,*}$, is given by

$$\pi^{S,prem}(\theta) \begin{cases} < (1-\lambda)w^N f^r & \text{if } \theta < \theta^{S,*} \\ = (1-\lambda)w^N f^r & \text{if } \theta = \theta^{S,*} \\ > (1-\lambda)w^N f^r & \text{if } \theta > \theta^{S,*} \end{cases}$$

with $0 < \lambda < 1$ denoting survival rate to exogenous "death shock".



Important: $w^N f^r$ denotes the offshoring market research sunk cost.

Dynamic model

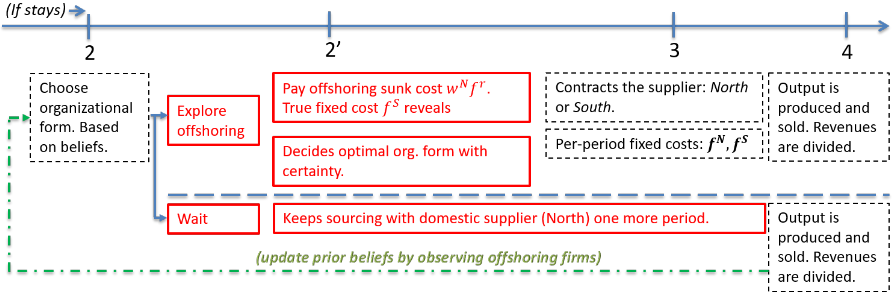
- **Initial conditions:**
  - Economy with non-tradable intermediate input (n.t.i).
  - No uncertainty in domestic fixed costs

- At $t = 0$: Transition to tradable intermediate inputs equilibrium begins. $\Rightarrow$ *Uncertainty about per-period fixed costs in South, f^S.*
  - With perfect information, the adjustment is instantaneous.
  - With uncertainty, the adjustment is sequential

Welfare considerations ($n.t.i.$ vs. perfect info steady states) App.: Price index

$$\underline{\theta}^{n.t.i.} < \underline{\theta}^{*} \quad ; \quad P^{n.t.i} > P^{*} \quad ; \quad Q^{n.t.i} < Q^{*}$$

Timing of events



Sectoral dynamic

- Characterized as a *Markov Decision Process (MDP)*, in which firms update their beliefs by a *recursive Bayesian process*.

"Beliefs" state

Appendix: Graph Prior

- Prior uncertainty about per-period fixed cost in South f^S $(t = 0)$:

$$f^S \sim Y(f^S) \quad \text{with} \quad f^S \in [\underline{f}^S, \bar{f}^S]$$

where $Y(.)$ denotes the c.d.f. of the prior distribution.

- Posterior $(t > 0)$

$$f^S \sim \begin{cases} Y(f^S | f^S \leq f_t^S) = \frac{Y(f^S | f^S \leq f_{t-1}^S)}{Y(f_t^S | f^S \leq f_{t-1}^S)} & \text{if } \tilde{f}_t^S = f_t^S < f_{t-1}^S \\ f_t^S & \text{if } \tilde{f}_t^S < f_t^S \end{cases}$$

f_t^S is the Revealed Upper Bound (R.U.B.) in t; and $\tilde{f}_t^S$ is the expected *R.U.B.* (related to least productive firm that tried offshoring in $t-1$).

"Physical" state

- $f^S(\theta)$: maximum affordable offshoring fixed cost for a firm θ

$$\pi^{S,prem}(\theta) = 0 \Rightarrow f^S(\theta) = \frac{r^{N,*}(\theta, Q_t)}{\sigma w^N}\left[\left(\frac{w^N}{w^S}\right)^{(1-\eta)(\sigma-1)} - 1\right] + f^N$$

- θ_t: the least productive offshoring firm in period t.

$$f_t^S \equiv f^S(\theta_t) = \frac{r^N(\theta_t, Q_t)}{\sigma w^N}\left[\left(\frac{w^N}{w^S}\right)^{(1-\eta)(\sigma-1)} - 1\right] + f^N$$

  f_t^S: the maximum fixed costs of production in South such that firm θ_t remains offshoring after entry in South in $t-1$.

- $\tilde{f}_t^S \equiv f^S(\tilde{\theta}_t)$; $\tilde{\theta}_t$ the least productive firm trying offshoring in $t-1$.

Dynamic model - Uncertainty

"Beliefs" state

Appendix: Graph Prior

- Prior uncertainty about per-period fixed cost in South f^S $(t = 0)$:

$$f^S \sim Y(f^S) \quad \text{with} \quad f^S \in [\underline{f}^S, \bar{f}^S]$$

where $Y(.)$ denotes the c.d.f. of the prior distribution.

- Posterior $(t > 0)$

$$f^S \sim \begin{cases} Y(f^S | f^S \leq f_t^S) = \frac{Y(f^S | f^S \leq f_{t-1}^S)}{Y(f_t^S | f^S \leq f_{t-1}^S)} & \text{if } \tilde{f}_t^S = f_t^S < f_{t-1}^S \\ f_t^S & \text{if } \tilde{f}_t^S < f_t^S \end{cases}$$

f_t^S is the *revealed upper bound* in t; and $\tilde{f}_t^S$ is the expected one. The latter is related to least productive firm that attempted offshoring in $t-1$.

Assumption A.1.: Information flow decreases over time

$$\frac{\partial [f_t^S - E(f^S | f^S \leq f_t^S)]}{\partial f_t^S} > 0$$

Offshoring decision

The firm must decide whether to explore her offshoring potential in South and pay the sunk cost $w^N f^r$, or wait.

Formally,

$$\mathcal{V}_t(\theta;\theta_t) = \max\left\{V_t^o(\theta;\theta_t); V_t^w(\theta;\theta_t)\right\}$$

where $V_t^o(\theta;.)$ is the value of offshoring and $V_t^w(\theta;.)$ is the value of waiting for a firm with productivity θ in t.

Dynamic model - Uncertainty

- Value of offshoring in period t

$$V_t^o(\theta;.) = \mathbb{E}_t\left[\max\left\{0; \sum_{\tau=t}^{\infty} \lambda^{\tau-t}\pi_\tau^{S,prem}(\theta)\right\}\middle| f^S \leq f_t^S\right] - w^N f^r$$

- Value of waiting in period t

$$V_t^w(\theta;.) = 0 + \lambda \mathbb{E}_t\left[\mathcal{V}_{t+1}(\theta;\theta_{t+1})\right]$$

The Bellman's equation:

$$\mathcal{V}_t(\theta;\theta_t) = \max\left\{V_t^o(\theta;\theta_t); \lambda\mathbb{E}_t\left[\mathcal{V}_{t+1}(\theta;\theta_{t+1})\right]\right\}$$

(By *Assumption A.1.*) $\Rightarrow$ In expectation at t, waiting for one period and trying offshoring in the following one, $V_t^{w,1}(.)$, dominates waiting for more periods.

$$V_t^{w,1}(\theta;\theta_t,\tilde{\theta}_{t+1}) > V_t^{w,2}(\theta;\theta_t,\tilde{\theta}_{t+2}) > .... > V_t^{w,n}(\theta;\theta_t,\tilde{\theta}_{t+n})$$

Thence,

$$\mathcal{V}_t(\theta;.) = \max\left\{\mathbb{E}_t\left[\max\left\{0;\sum_{\tau=t}^{\infty}\lambda^{\tau-t}\pi_\tau^{S,prem}(\theta)\right\}\middle| f^S \leq f_t^S\right] - w^N f^r; V_t^{w,1}(\theta;.)\right\}$$

$\Rightarrow$ One-Step-Look-Ahead (OSLA) rule is the optimal policy.

Offshoring decision for any period t determined by the trade-off function:

$$\mathcal{D}_t(\theta;\theta_t,\tilde{\theta}_{t+1}) = V_t^o(\theta;\theta_t,\tilde{\theta}_{t+1}) - V_t^{w,1}(\theta;\theta_t,\tilde{\theta}_{t+1})$$

At any time t, firm's offshoring decision is based on:

$$\mathcal{D}_t(\theta;.)\begin{cases}\geq 0 \Rightarrow & \text{pays the sunk cost and discovers her offshoring potential.}\\ < 0 \Rightarrow & \text{remains sourcing domestically for one more period.}\end{cases}$$

Proposition 1: Sequential offshoring *Firms with higher productivity have an incentive to explore offshoring in early periods.*

$$\frac{\partial \mathcal{D}_t(\theta; \theta_t, \tilde{\theta}_{t+1})}{\partial \theta} \geq 0$$

In other words, firms explore offshoring sequentially, led by the most productive ones in the market.

Trade-off function: Using Proposition 1, it is given by

$$\mathcal{D}_t(\theta; \theta_t, \tilde{\theta}_{t+1}) = \max \left\{ 0; \mathbb{E}_t \left[\pi_t^{S,prem}(\theta) \middle| f^S \leq f_t^S \right] \right\} - w^N f^r \left[1 - \lambda \frac{Y(f_{t+1}^S)}{Y(f_t^S)} \right]$$

with $\frac{Y(f_{t+1}^S)}{Y(f_t^S)} \equiv Y(f_{t+1}^S | f^S \leq f_t^S)$

Proposition 2: Per-period offshoring cutoff *The offshoring cutoff $\tilde{\theta}_{t+1}$ at every period t is defined as the fixed point in the trade-off function*

$$\mathcal{D}_t(\tilde{\theta}_{t+1}; \theta_t, \tilde{\theta}_{t+1}) = 0$$

$$\mathbb{E}_t \left[\pi_t^{S,prem}(\tilde{\theta}_{t+1}) \middle| f^S \leq f_t^S \right] = w^N f^{r,S} \left[1 - \lambda \frac{Y(f_{t+1}^S)}{Y(f_t^S)} \right]$$

Thus, solving for $\tilde{\theta}_{t+1} \equiv \theta_t^S$, it expresses the offshoring productivity cutoff at period t. App. Offsh. Cutoff

Learning mechanism

- If $f^S = \underline{f}^S \Rightarrow$ The distribution collapses in the lower bound of the prior.
- If $f^S \in (\underline{f}^S, \bar{f}^S] \Rightarrow$ Updating stops sooner (true value revealed).

Convergence analysis

$$\mathcal{D}(\theta_\infty; \theta_\infty, \theta_\infty) = 0$$

$$\mathbb{E}_t \left[\pi^{S,prem}(\theta^S_\infty) \middle| f^S \leq f^S_\infty \right] = w^N f^{r,S} (1 - \lambda)$$

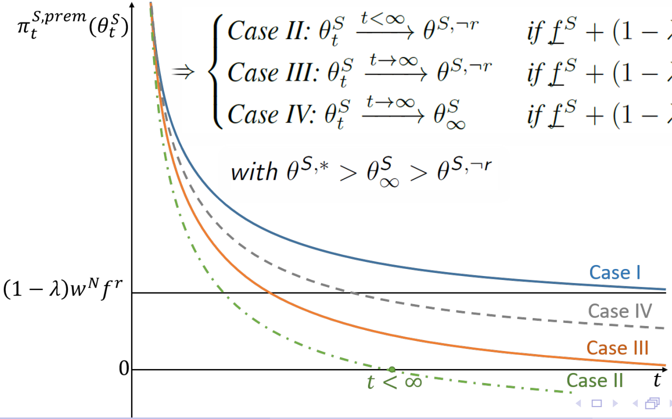
Proposition 4: Long run properties of the equilibrium. *The economy converges asymptotically to the full information equilibrium when*

$$\text{Case I: } f^S = \underline{f}^S \Rightarrow f^S_\infty = \underline{f}^S \Rightarrow \theta^S_t \xrightarrow{t\to\infty} \theta^{S,*}$$

Otherwise, if $f^S > \underline{f}^S$*, it leads to over-offshoring converging to*

$$\Rightarrow \begin{cases} \text{Case II: } \theta^S_t \xrightarrow{t<\infty} \theta^{S,\neg r} & \text{if } \underline{f}^S + (1-\lambda)f^r < f^S \\ \text{Case III: } \theta^S_t \xrightarrow{t\to\infty} \theta^{S,\neg r} & \text{if } \underline{f}^S + (1-\lambda)f^r = f^S \\ \text{Case IV: } \theta^S_t \xrightarrow{t\to\infty} \theta^S_\infty & \text{if } \underline{f}^S + (1-\lambda)f^r > f^S > \underline{f}^S \end{cases}$$

$$\text{with } \theta^{S,*} > \theta^S_\infty > \theta^{S,\neg r}$$



North-South model: Summary of results

Main results

- The industry takes a sequential offshoring dynamic, led by the most productive firms in the market.
- Informational spillovers and learning allow the economy to reach the perfect information steady state (*with some excessive offshoring*).
- The steady state can be reached in a finite time when the prior beliefs are very optimistic (*Case II*). Otherwise, it is reached in the long run.
- Welfare gains from offshoring are fully achieved in the long run.

NOW, I extend the model to a multi-country world

3 countries: Uncertainty

World economy: North - East - South

- Potential offshoring locations: East and South.

Assumptions

- Institutional fundamentals in the South are better than in North: $f^S < f^E \Rightarrow$ But this is unknown to firms.
- Symmetric wages: $A_{0,S} = A_{0,E} \Rightarrow w^S = w^E$.
- Symmetric offshoring market research costs, i.e. $f^{r,S} = f^{r,E} = f^r$.

Prior beliefs: Symmetric and asymmetric prior beliefs.

Firms' decisions (two stages)

$$\mathcal{V}_t(\theta;.) = \max\left\{\max\left\{V_t^{o,S}(\theta;.); V_t^{o,E}(\theta;.)\right\}; \lambda\mathbb{E}_t\left[\mathcal{V}_{t+1}(\theta;.)\right]\right\}$$

$$\Rightarrow \mathcal{V}_t(\theta;.) = \max\left\{V_t^{o,l}(\theta;\theta_t^l,\tilde{\theta}_{t+1}^l); V_t^{w,1,l}(\theta;\theta_t^l,\tilde{\theta}_{t+1}^l)\right\};\ \text{with } l = \{E \veebar S\}$$

3 countries: Uncertainty - Multiple equilibria

Case A: Symmetric prior beliefs

- Beliefs

$$\underline{f}^S = \underline{f}^E = \underline{f} \wedge \bar{f}^S = \bar{f}^E = \bar{f}; \text{ both with distribution } Y(.)$$

- Steady state with pessimistic beliefs, i.e. $(1-\lambda)f^r \geq f^E - \underline{f} \geq 0$:

$$\theta^E_\infty < \infty \text{ and } \theta^S_t \downarrow \theta^S_\infty = \theta^{S,*} \Rightarrow P_t \downarrow P^* \Rightarrow Q_t \uparrow Q^*$$

- Steady state with optimistic beliefs, i.e. $\underline{f} + (1-\lambda)f^r < f^E$:
  - Sequential relocation $(E \to S)$ of least productive offshoring firms.
  - Relocation $(E \to S)$ of most productive firms offshoring in East: Only if difference in fundamentals is large enough, i.e.

$$f^E - \mathbb{E}_t[f^S | f^S \leq f^S_t] \geq (1-\lambda)f^r$$

  - Steady state with relocation:

$$\theta^E_t \to \infty \text{ and } \theta^S_t \downarrow \theta^S_\infty = \theta^{S,*} \Rightarrow P_t \downarrow P^* \Rightarrow Q_t \uparrow Q^*$$

3 countries: Uncertainty - Multiple equilibria

Case B: (asymmetric priors) **Coordination in good equilibrium**

- Beliefs

$$\underline{f}^S = \underline{f}^E = \underline{f} \wedge \bar{f}^S = \bar{f}^E - \delta; \text{ with } \delta > 0$$
$$\Rightarrow \mathbb{E}_{t=0}(f^S | f^S \leq \bar{f}^S) < \mathbb{E}_{t=0}(f^E | f^E \leq \bar{f}^E)$$

- Evolution of beliefs over time

$$f^E \sim Y(f^E) \text{ with } f^E \in [\underline{f}^E, \bar{f}^E]$$
$$f^S \sim \begin{cases} Y(f^S | f^S \leq f_t^S) & \text{if } \tilde{f}_t^S = f_t^S < f_{t-1}^S \\ f_t^S & \text{if } \tilde{f}_t^S < f_t^S \end{cases}$$

- Steady state:

$$\theta_t^E \to \infty \forall t \text{ and } \theta_t^S \downarrow \theta^{S,*} \Rightarrow P_t \downarrow P^* \Rightarrow Q_t \uparrow Q^*$$

3 countries: Uncertainty - Multiple equilibria

Case C: (asymmetric priors) **Coordination in bad equilibrium**

- Beliefs

$$\underline{f}^S = \underline{f}^E = \underline{f} \wedge \bar{f}^S = \bar{f}^E - \delta; \text{ with } \delta < 0$$
$$\Rightarrow \mathbb{E}_{t=0}(f^S | f^S \leq \bar{f}^S) > \mathbb{E}_{t=0}(f^E | f^E \leq \bar{f}^E)$$

- Evolution of beliefs over time

$$f^S \sim Y(f^S) \text{ with } f^S \in [\underline{f}^S, \bar{f}^S]$$
$$f^E \sim \begin{cases} Y(f^E | f^E \leq f_t^E) & \text{if } \tilde{f}_t^E = f_t^E < f_{t-1}^E \\ f_t^E & \text{if } \tilde{f}_t^E < f_t^E \end{cases}$$

- Possible steady states:

$$\theta_t^S \to \infty \forall t \text{ and } \theta_t^E \downarrow \theta_\infty^E > \theta^{S,*} \Rightarrow P_t \downarrow P_\infty > P^* \Rightarrow Q_t \uparrow Q_\infty < Q^*$$

or

$$\theta_t^E \to \{\theta_{t=1}^E \veebar \infty\} \text{ and } \theta_t^S \downarrow \theta^{S,*} \Rightarrow P_t \downarrow P^* \Rightarrow Q_t \uparrow Q^*$$

Conclusions

- Firms find risky to explore their offshoring potential in each possible location.
- Informational externalities and learning may not drive the economy any more to the perfect information steady state.
  - Welfare implications.
  - Inefficient allocation of production across countries.
- Selection pattern in countries: Increasing differentiation of countries driven by informational spillovers.
- *Revealed* comparative advantages: the specialisation of countries is driven by information spillovers.
- The scope of informational externalities may affect the dynamic of specialisation. If sector-specific spillovers ⇒ Sectoral specialization.

Conclusions and Extensions

Policy implications

- New questions about effectiveness of institutional reforms.
- The effect of a reform in attracting offshoring reduces when spillovers have already had strong impact in countries differentiation.
- Role of international institutions in firms' beliefs formation.

Extensions and next steps

- Wages respond to offshoring flows
  - Sequence in countries (relocation)
- Incomplete contracts
  - Offshoring decision implies more dimensions (property rights approach): location + ownership.
- Contractual frictions
  - Offshoring decision dimensions: location + ownership.
  - Uncertainty in the contractibility degree.
- Empirical model

Thanks

Leandro Navarro
Chair of International Finance
Johannes Gutenberg University Mainz
lenavarr@uni-mainz.de

Appendix: *Assumption on fixed cost and wages for ranking*

$$\frac{f^S + (1-\lambda)f^r}{f^N} > \left(\frac{w^N}{w^S}\right)^{(1-\eta)(\sigma-1)}$$

back-Timing Events

- **Profits**

$$\pi^l(\theta,.) = \theta^{\sigma-1}((! - \gamma_0)E)^\sigma Q^{1-\sigma}\psi^l - w^N f^l$$

with $l = \{N, S\}$, and ψ^l is defined as: $\psi^l \equiv \frac{\alpha^{\sigma-1}}{\sigma\left[(w^N)^\eta (w^l)^{1-\eta}\right]^{\sigma-1}}$

- **Profit premium**

$$\pi^{S,prem}(\theta) \equiv \pi^S(\theta) - \pi^N(\theta) = \frac{r^N(\theta)}{\sigma}\left[\left(\frac{w^N}{w^S}\right)^{(1-\eta)(\sigma-1)} - 1\right] - w^N\left[f^S - f^N\right]$$

- **Price of domestic sourcing firm vs. Price of offshoring firm**

$$p(\theta) = \frac{w^N}{\alpha\theta} > p^{off}(\theta) = \frac{(w^N)^\eta (w^S)^{1-\eta}}{\alpha\theta}$$

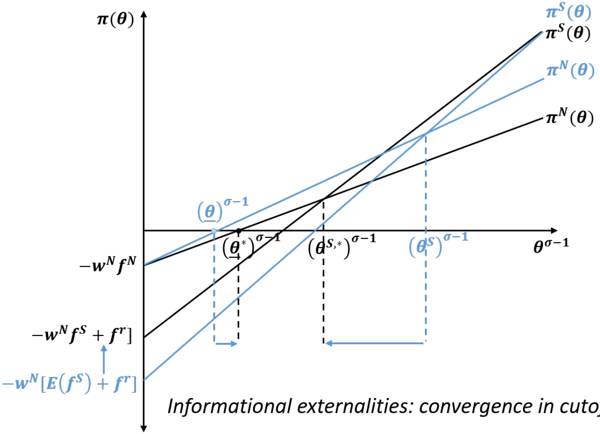
- **Price index**

$$P^{1-\sigma} = \left(P^{\text{n.t.i.}}\right)^{1-\sigma} + \frac{1 - G(\theta^{S,*})}{1 - G(\underline{\theta}^*)}\left[\left(\frac{w^N}{w^S}\right)^{(1-\eta)(\sigma-1)} - 1\right]\left(P^{\text{off}|\text{n.t.i.}}\right)^{1-\sigma}$$

back-PI back-Dynamic

Appendix: *Dynamic model - Uncertainty*

- Uncertainty in $f^S \Rightarrow$ Prior beliefs
- Firms can learn $\Rightarrow$ Informational externalities



Informational externalities: convergence in cutoffs

back

Appendix: *Uncertainty*

Per-Period Equilibrium Offshoring Cutoff

$$\theta_t^S = [(1-\gamma_0)E]^{\frac{\sigma}{1-\sigma}} \, Q_t \left[\frac{w^N \left[\mathbb{E}_t(f^S | f^S \leq f_t^S) - f^N + \left(1 - \lambda \frac{Y(f_{t+1}^S)}{Y(f_t^S)}\right) f^r \right]}{\psi^S - \psi^N} \right]^{\frac{1}{\sigma - 1}}$$

back