Uncertainty in Global Sourcing
Learning, sequential offshoring, and selection patterns

Leandro Navarro

Johannes Gutenberg University Mainz

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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 ⇒ Vague knowledge about the existing infrastructure and institutions, particularly abroad.
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.
  \[\Rightarrow \text{revealed comparative advantages.}\]
Literature Review

- **On heterogeneous firms, trade and global sourcing**

- **On uncertainty, trade, global sourcing**

- **On Markov processes, Statistical decisions, Informational externalities, Bayesian learning**

- **On comparative advantages**
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):
  \[ Q_t = \left[ \int_{i \in I_t} q_t(i)^\alpha \, di \right]^{1/\alpha}, \quad 0 < \alpha < 1 \]

\( q_t(i) \) 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).
Model setup

Technology

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

Differentiated sector

- Variety $i$’s production function (in North):
  \[
  q_t(i) = \theta \left( \frac{x_{h,t}(i)}{\eta} \right)^\eta \left( \frac{x_{m,t}(i)}{1 - \eta} \right)^{1-\eta}; \quad 0 < \eta < 1
  \]
  
  - $x_{h,t}$: HQ services, supplied by the headquarter $H$.
  - $x_{m,t}$: intermediate input, supplied by the supplier $M$ in North or South.

- Both inputs are produced with constant return technologies.
Perfect information model (AH2004)
Organizational choice - Timing of events

Organizational choices: Domestic sourcing \((\text{North})\) vs. Offshoring \((\text{South})\)

Timing of events

- Pay sunk entry cost \(f_e\)
- Productivity draw from \(G(\theta)\)
- Exit the market or remain active
- Choose organizational form: Offshore or domestic sourcing
- If offshoring: pays sunk cost \(f^T\)
- Contracts the supplier: \(\text{North}\) or \(\text{South}\)
- Per-period fixed costs: \(f^N\), \(f^S\)
- Output is produced and sold. Revenues are divided.

- \(f_e\): market entry sunk cost
- \(f^T\): 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

\[ f^N < f^S \]
Offshoring profit premium (per-period) \(\text{App.: Profit}\)

\[
\pi_{S,\text{prem}}(\theta) \equiv \pi^S(\theta) - \pi^N(\theta)
\]

Offshoring cutoff, \(\theta^S,^*\), is given by

\[
\pi_{S,\text{prem}}(\theta) \begin{cases} 
< (1 - \lambda)w^Nf^r & \text{if } \theta < \theta^S,^* \\
= (1 - \lambda)w^Nf^r & \text{if } \theta = \theta^S,^* \\
> (1 - \lambda)w^Nf^r & \text{if } \theta > \theta^S,^*
\end{cases}
\]

with \(0 < \lambda < 1\) denoting survival rate to exogenous ”death shock”.

**Important:** \(w^Nf^r\) 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. ⇒ *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)

$$\theta^{n.t.i.} < \theta^* ; \quad P^{n.t.i} > P^* ; \quad Q^{n.t.i} < Q^*$$
Dynamic model - Uncertainty

The Model - **Timing of events**

**Timing of events**

(If stays) → 2 → 2′ → 3 → 4

- Choose organizational form. Based on beliefs.
- Explore offshoring
  - Pay offshoring sunk cost $w^N f^r$. True fixed cost $f^S$ reveals
  - Decides optimal org. form with certainty.
- Wait
  - Keeps sourcing with domestic supplier (North) one more period.

(Update prior beliefs by observing offshoring firms)

Contracts the supplier: *North* or *South*.
Per-period fixed costs: $f^N, f^S$
Output is produced and sold. Revenues are divided.

**Sectoral dynamic**

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

"Beliefs" state

- **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** ($t > 0$)
  $$f^S \sim \begin{cases} Y(f^S | f^S \leq f^S_t) = \frac{Y(f^S | f^S \leq f^S_{t-1})}{Y(f^S_t | f^S \leq f^S_{t-1})} & \text{if } \tilde{f}^S_t = f^S_t < f^S_{t-1} \\ f^S_t & \text{if } \tilde{f}^S_t < f^S_t \end{cases}$$

$f^S_t$ is the Revealed Upper Bound (R.U.B.) in $t$; and $\tilde{f}^S_t$ 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 $\theta$

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

- $\theta_t$: 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 $\theta_t$ 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
Decision under uncertainty - Markov Decision Process - "Beliefs" state definition

"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 ($t > 0$)
  \[
  f^S \sim \begin{cases} 
  Y(f^S|f^S \leq f^S_t) = \frac{Y(f^S|f^S \leq \bar{f}^S_{t-1})}{Y(f^S|f^S \leq \bar{f}^S_{t-1})} & \text{if } \tilde{f}^S_t = f^S_t < f^S_{t-1} \\
  f^S_t & \text{if } \tilde{f}^S_t < f^S_t 
  \end{cases}
  \]

$f^S_t$ is the revealed upper bound in $t$; and $\tilde{f}^S_t$ 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

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

$$V_t(\theta; \theta_t) = \max \{ V_t^o(\theta; \theta_t); V_t^w(\theta; \theta_t) \}$$

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 $\theta$ in $t$. 
Dynamic model - Uncertainty
Equilibrium path - Sequential offshoring - Offshoring decision - Offshoring and Waiting

○ Value of offshoring in period $t$

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

○ Value of waiting in period $t$

$$ V^w_t(\theta; .) = 0 + \lambda \mathbb{E}_t [V_{t+1}(\theta; \theta_{t+1})] $$

The Bellman’s equation:

$$ V_t(\theta; \theta_t) = \max \left\{ V^o_t(\theta; \theta_t); \lambda \mathbb{E}_t [V_{t+1}(\theta; \theta_{t+1})] \right\} $$
(By Assumption A.1.) ⇒ In expectation at $t$, waiting for one period and trying offshoring in the following one, $V_{t,1}^{w}(\cdot)$, dominates waiting for more periods.

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

Thence,

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

⇒ One-Step-Look-Ahead (OSLA) rule is the optimal policy.
Dynamic model - Uncertainty
Equilibrium path - Sequential offshoring - **Offshoring decision**

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

$$D_t(\theta; \theta_t, \tilde{\theta}_{t+1}) = V^o_t(\theta; \theta_t, \tilde{\theta}_{t+1}) - V^{w,1}_t(\theta; \theta_t, \tilde{\theta}_{t+1})$$

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

$$D_t(\theta; \theta_t, \tilde{\theta}_{t+1}) \begin{cases} 
\geq 0 & \Rightarrow \text{pays the sunk cost and discovers her offshoring potential.} \\
< 0 & \Rightarrow \text{remains sourcing domestically for one more period.}
\end{cases}$$
Proposition 1: Sequential offshoring *Firms with higher productivity have an incentive to explore offshoring in early periods.*

\[
\frac{\partial D_t(\theta; \theta_t, \tilde{\theta}_{t+1})}{\partial \theta} \geq 0
\]

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

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

with \( \frac{Y(f^S_{t+1})}{Y(f^S_t)} \equiv Y(f^S_{t+1} \mid f^S \leq f^S_t) \)
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

\[
D_t(\tilde{\theta}_{t+1}; \theta_t, \tilde{\theta}_{t+1}) = 0
\]

\[
E_t \left[ \frac{\pi_t^{S,\text{prem}}(\tilde{\theta}_{t+1})}{\pi_t^S} \bigg| f^S \leq f_t^S \right] = w^N f^{r,S} \left[ 1 - \lambda \frac{Y(f_t^S)}{Y(f_t^{S})} \right]
\]

Thus, solving for \( \tilde{\theta}_{t+1} \equiv \theta_t^S \), it expresses the offshoring productivity cutoff at period \( t \).
Learning mechanism

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

Convergence analysis

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

$$\mathbb{E}_t \left[ \pi^{S, prem}(\theta_\infty) \left| f^S \leq f_S \right. \right] = w^N f^{r,S} (1 - \lambda)$$
Proposition 4: **Long run properties of the equilibrium.** The economy converges asymptotically to the full information equilibrium when

\[ f^S = \underline{f}^S \Rightarrow f^S_t \xrightarrow{t \to \infty} \theta^S_t \xrightarrow{t \to \infty} \theta^S,* \]

Case I:

\[ f^S < \underline{f}^S \]

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

\[ \pi_{t,\text{prem}}^S(\theta^S_t) \]

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

with \( \theta^S,* > \theta^S_{\infty} > \theta^S,,-r \)
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)

\[
V_t(\theta;.) = \max \left\{ \max \left\{ V_t^{o,S}(\theta;.) ; V_t^{o,E}(\theta;.) \right\} ; \lambda E_t [V_{t+1}(\theta;.)] \right\}
\]

\[
V_t(\theta;.) = \max \left\{ V_t^{o,l}(\theta;\theta^l_t, \tilde{\theta}^l_{t+1}); V_t^{w,1,l}(\theta;\theta^l_t, \tilde{\theta}^l_{t+1}) \right\} ; \text{ with } l = \{E \vee S\}
\]
Case A: Symmetric prior beliefs

Beliefs

\[ f^S = f^E = f \land \bar{f}^S = \bar{f}^E = \bar{f}; \] both with distribution \( Y(.) \)

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

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

Steady state with optimistic beliefs, i.e. \( f + (1 - \lambda)f^r < f^E:\)

Sequential relocation (\( E \rightarrow S \)) of least productive offshoring firms.

Relocation (\( E \rightarrow S \)) 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:

\[ \theta^E_t \rightarrow \infty \text{ and } \theta^S_t \downarrow \theta^S_\infty = \theta^{S,*} \Rightarrow P_t \downarrow P^* \Rightarrow Q_t \uparrow Q^* \]
3 countries: Uncertainty - Multiple equilibria

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

- **Beliefs**

  \[ f^S = f^E = f \land \bar{f}^S = \bar{f}^E - \delta; \text{ with } \delta > 0 \]

  \[ \Rightarrow E_{t=0}(f^S \mid f^S \leq \bar{f}^S) < E_{t=0}(f^E \mid f^E \leq \bar{f}^E) \]

- **Evolution of beliefs over time**

  \[ f^E \sim Y(f^E) \text{ with } f^E \in [f^E, \bar{f}^E] \]

  \[ f^S \sim \begin{cases} Y(f^S \mid f^S \leq f^S_t) & \text{if } \bar{f}^S_t = f^S_t < f^S_{t-1} \\ f^S_t & \text{if } \bar{f}^S_t < f^S_t \end{cases} \]

- **Steady state:**

  \[ \theta^E_t \to \infty \forall t \text{ and } \theta^S_t \downarrow \theta^{*,S} \Rightarrow P_t \downarrow P^* \Rightarrow Q_t \uparrow Q^* \]
3 countries: Uncertainty - Multiple equilibria

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

- **Beliefs**

  \[ f^S = f^E = f \land \bar{f}^S = \bar{f}^E - \delta; \text{ with } \delta < 0 \]

  \[ \Rightarrow \mathbb{E}_{t=0}(f^S | f^S \leq \bar{f}^S) > \mathbb{E}_{t=0}(f^E | f^E \leq \bar{f}^E) \]

- **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

  \[
  \theta_t^E \to \{ \theta_t^E \lor \infty \} \text{ and } \theta_t^S \downarrow \theta^S,* \Rightarrow P_t \downarrow P^* \Rightarrow Q_t \uparrow Q^*
  \]
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

\[
\frac{f^S + (1 - \lambda) f^r}{f^N} > \left( \frac{w^N}{w^S} \right)^{(1-\eta)(\sigma-1)}
\]
Appendix: Profit function - Price index

- **Profits**
  \[ \pi^l(\theta, .) = \theta^{\sigma-1}((1 - \gamma_0)E)^\sigma Q^{1-\sigma} \psi^l - w^N f^l \]
  with \( l = \{N, S\} \), and \( \psi^l \) is defined as:
  \[ \psi^l \equiv \frac{\alpha^{\sigma-1}}{\sigma[(w^N)^\eta(w^l)^{1-\eta}]^{\sigma-1}} \]

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

- **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**
  \[ P^{1-\sigma} = (P^{n.t.i.})^{1-\sigma} + \frac{1 - G(\theta^{S,*})}{1 - G(\theta^*)} \left[ \left( \frac{w^N}{w^S} \right)^{(1-\eta)(\sigma-1)} - 1 \right] (P^{off|n.t.i.})^{1-\sigma} \]
Appendix: *Dynamic model - Uncertainty*

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

**Informational externalities: convergence in cutoffs**
Appendix: Uncertainty

Per-Period Equilibrium Offshoring Cutoff

\[
\theta^S_t = \left[ (1 - \gamma_0) E \right]^{\frac{\sigma}{1 - \sigma}} Q_t \left[ w^N \left[ E_t (f^S | f^S \leq f^S_t) - f^N + \left( 1 - \lambda \frac{Y(f^S_{t+1})}{Y(f^S_t)} \right) f^r \right] \right] \frac{1}{\sigma - 1} \psi^S - \psi^N
\]