GLOBAL SOURCING UNDER EXCHANGE-RATE UNCERTAINTY

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Model setup
## Demand Uncertainty

~ Uniform[0,200]

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Price = $100

**No Dual Sourcing**
Research Questions

1. Onshore sourcing, Offshore sourcing or Dual sourcing?

2. How do uncertainties impact the firm’s sourcing decisions?

3. What are the key drivers?
Related literature

- **Sourcing Decisions**
  - Burke, Carillo & Vakharia (2007)
  - Wu & Zhang (2014)
  - Feng & Lu (2012)

- **Dual/Multi sourcing**
  - Kouvelis & Li (2013)
  - Sting & Huchzermeier (2010)
  - Lu & Van Mieghem (2009)
  - Burke, Carillo & Vakharia (2009)
  - Tomlin & Wang (2005)
  - Serel, Dada & Moskowitz (2001)
  - Dada, Petruzzi & Schwarz (2007)
  - Fox, Metters & Semple (2006)

- **Allon & Van Mieghem (2010)**
  - No exchange-rate uncertainty
  - Dual sourcing is assumed
  - Asymmetric and positive lead times

- **Li & Wang (2010)**
  - Production decisions after realizing demand
  - Limited optimal solution characterization
The Model

\[ p \quad \text{Selling Price/Unit} \]

\[ e \quad \text{Currency Exchange-Rate} \]

\[ \tilde{x} \quad \text{Demand} \]

\[ c^k_H \quad \text{Capacity Reservation Cost/Unit} \]

\[ c^v_H \quad \text{Variable Operational Costs/Unit} \]

\[ c^k_F \]

\[ c^v_F \]
Demand uncertainty

Realizations:

Decisions:

Stage 1

Capacity Reservations
\((Q_H, Q_F)\)

Stage 2

Production Quantity
\((q_H, q_F)\)

Demand
\((X \sim F(x))\)

No Dual Sourcing
The model

Stage 1

Realizations:

Decisions:
Capacity Reservations \((Q_H, Q_F)\)

Stage 2

Exchange Rate \((\tilde{\epsilon})\)

Demand \((X \sim F(x))\)

Production Quantity \((q_H, q_F)\)
Onshore sourcing

Realizations:
- Exchange Rate ($\tilde{\epsilon}$)

Decisions:
- Capacity Reservations ($Q_H$)
- Production Quantity ($q_H$)

Optimal Capacity:
$$Q_H^o = F^{-1}\left(\frac{p - c_H^v - c_H^k}{p}\right)$$

Unconstrained Optimal Production:
$$q_H^o = F^{-1}\left(\frac{p - c_H^v}{p}\right) > Q_H^o$$

Demand ($X \sim F(x)$)
Offshore sourcing

Stage 1

Realizations:
- Demand $X \sim F(x)$
- Exchange Rate $\tilde{e}$

Decisions:
- Capacity Reservations $(Q_F)$

Stage 2

Exchange Rate $(\tilde{e})$

Production Quantity $(q_F)$

Optimal Capacity $= Q_F^o$

Unconstrained Optimal Production $= q_F^o(e)$

$$-c_F^k + \int_{\tilde{e}}^p \left[ 1 - F(Q_F) \right] \frac{g(e)}{c_F^\gamma} \left( p \left[ 1 - F(Q_F) \right] - c_F^\gamma e \right) g(e) \, de = 0$$

$$q_F^o(e) = F^{-1} \left( \frac{p - c_F^\gamma e}{p} \right)$$
Global sourcing

**Realizations:**
- Stage 1
- Stage 2

**Decisions:**
- Capacity Reservations ($Q_H, Q_F$)
- Production Quantity ($q_H, q_F$)
- Exchange Rate ($\tilde{e}$)
- Demand ($X \sim F(x)$)

$t$
Formulation

- **Stage 1: Amount of capacity to be reserved** \((Q_H, Q_F)\)

\[
E[\Pi(Q_H, Q_F)] = -c^k_H Q_H - c^k_F Q_F + E[\pi^*(Q_H, Q_F, e)]
\]

- **Stage 2: Amount of products to be manufactured** \((q_H, q_F)\)

\[
\pi^*(Q_H, Q_F, e) = \max_{0 \leq q_H \leq Q_H, 0 \leq q_F \leq Q_F} E[\pi(q_H, q_F | Q_H, Q_F, e)]
\]

\[
\pi(q_H, q_F | Q_H, Q_F, e) = -c^p_H q_H - c^p_F eq_F + p \min\{x, q_H + q_F\}
\]
Global sourcing: Stage 2

Exchange-rate realization in the 2\textsuperscript{nd} stage:

\[ 0 < m_H < m_F \quad 0 < m_F < m_H \quad m_F < 0 < m_H \]

Realized profit margins in the 2\textsuperscript{nd} stage: \[ m_H = p - c_H^v, \quad m_F = p - c_F^v e \]

Onshore profit margin in the 1\textsuperscript{st} stage: \[ M_H = p - c_H^v - c_H^k > 0 \]
Potentially optimal solutions

\[ c_F^k + c_F^v < c_H^k + c_H^v \]

Offshore

Dual (D2)

Excess

Dual (D1)

Rationing

\[ c_H^k + c_H^v < c_F^k + c_F^v \]
# Optimal policies and conditions

## Optimal Sourcing Policy

<table>
<thead>
<tr>
<th>Optimal Sourcing Policy</th>
<th>Onshore Sourcing</th>
<th>Offshore Sourcing</th>
<th>Dual Sourcing</th>
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<tbody>
<tr>
<td>OC1: ( E\left[\left(\tilde{m}_F^+ - m_H\right)^+\right] - c_F^k &gt; 0 )</td>
<td>×</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>OC2: ( E\left[\left(m_H - \tilde{m}_F^+\right)^+\right] - c_H^k &gt; 0 )</td>
<td>×</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>OC3: ( E\left[\left(\tilde{m}_F^+ - M_H\right)^+\right] - c_F^k &gt; 0 )</td>
<td>×</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>OC4: ( m_H - c_H^k - \left(E\left[\tilde{m}_F^+\right] - c_F^k\right) &gt; 0 )</td>
<td>×</td>
<td>✓</td>
<td></td>
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</table>

**Table 1.** Necessary and sufficient conditions for the first-stage optimal decisions.  
✓ optimality condition holds when a particular sourcing policy is optimal; × opposite inequality holds
### Policies under exchange-rate uncertainty

<table>
<thead>
<tr>
<th>Cost Structure</th>
<th>Demand Uncertainty</th>
<th>Optimality Conditions</th>
<th>Exchange-rate and Demand Uncertainty</th>
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<tbody>
<tr>
<td></td>
<td>Offshore Sourcing</td>
<td>OC1</td>
<td>Dual Sourcing (D2)</td>
</tr>
<tr>
<td>Case 1</td>
<td></td>
<td>OC2</td>
<td>Offshore Sourcing (F2)</td>
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<tr>
<td>$c_F^k + c_F^v &lt; c_H^k + c_H^v$</td>
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<td>Dual Sourcing (D2)</td>
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<tr>
<td>Case 2</td>
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<td>OC2</td>
<td>Offshore Sourcing (F2)</td>
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<tr>
<td>$c_F^k + c_F^v \geq c_H^k + c_H^v$</td>
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<td>OC2~</td>
<td>Offshore Sourcing (F1)</td>
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<td></td>
<td>OC3</td>
<td>Dual Sourcing (D1)</td>
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<tr>
<td></td>
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<td>OC4</td>
<td>Offshore Sourcing (F1)</td>
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<td>Onshore Sourcing (H1)</td>
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Incorporating exchange-rate uncertainty

- Low cost foreign source (Case 1)
  - Offshore sourcing, or
  - Dual source with excess capacity

- Low cost domestic source (Case 2)
  - All five optimal solutions are possible
  - Offshore with no domestic capacity is possible
    - Both F1 and F2 can occur
Demand Uncertainty
~ Uniform[0,200]

and

Exchange-rate Uncertainty
~ Uniform[0,2]

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Price = $100

- Only F
- Variable Cost > Price
- Dual Source
Impact of exchange-rate volatility

- Mean-preserving spread of exchange rate
  - Second-degree stochastic dominance
- $Q_F^*$ increases in exchange-rate volatility
- $Q_H^*$ may increase or decrease in exchange-rate volatility

- Offshoring and dual sourcing policies
  - Expected profit always increases in exchange-rate volatility
Impact of exchange-rate volatility

- **Numerical Illustration**
  - Exchange-rate $\sim$ Uniform$[1-d,1+d]$ \hspace{1cm} $d$: Half spread
  - Demand $\sim$ Uniform$[0,200]$
  - Price = $100

![Diagram showing exchange-rate volatility with half spread $d$ and demand range]
Low cost offshore source

(a) \( c_H^k = 8, c_H^v = 60, c_F^k = 10, c_F^v = 55 \)

(b) \( c_H^k = 8, c_H^v = 60, c_F^k = 10, c_F^v = 55 \)
Low cost onshore source

(a) $c^k_H = 4, c^v_H = 88, c^k_F = 16, c^v_F = 78$

(b) $c^k_H = 20, c^v_H = 65, c^k_F = 15, c^v_F = 75$
Low cost onshore source

\( Q_H^* \) \hspace{1cm} \( Q_F^* \)

(c) \( c_H^k = 8, c_H^v = 65, c_F^k = 15, c_F^v = 60 \)

(d) \( c_H^k = 18, c_H^v = 50, c_F^k = 4, c_F^v = 72 \)
Concluding Remarks

- Demand uncertainty by itself never leads to dual sourcing

1) Exchange-rate uncertainty is the main driver of dual sourcing
   a) Determined potentially optimal sourcing policies (five optimal solutions)
   b) Identified the conditions that lead to them
   c) Demonstrated the impact of exchange-rate uncertainty on optimal capacity reservation decisions
   d) Onshore sourcing under demand uncertainty can become offshore sourcing under exchange-rate and demand uncertainty

2) The foreign country’s lower cost is neither a necessary nor a sufficient condition for offshore sourcing
   a) Capacity can be reserved even when (variable) cost > price

3) Two types of dual sourcing: (1) Rationing (2) Excess capacity

4) Impact of increasing exchange-rate volatility
   a) Increased expected profit for offshore and dual sourcing policies
   b) Greater capacity commitment at the offshore source
   c) Capacity commitment may increase or decrease at the onshore source
Thank You!