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# RESEARCH OVERVIEW ON INTERNATIONAL OPERATIONS

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*Presentation By:*

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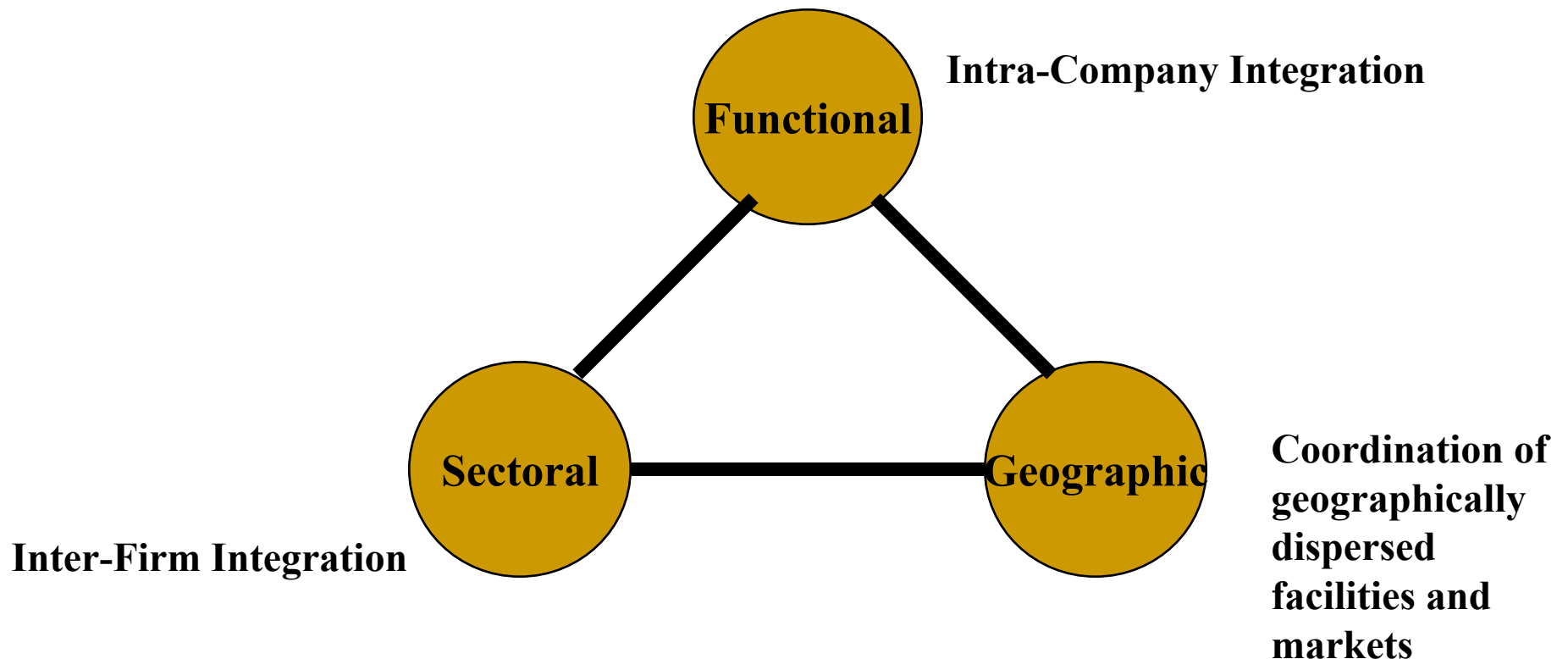
# PRESENTATION OUTLINE

- Selective Research Overview of the International Operations / Global Supply Chain Research of the Last 10 Years
  - Studied issues
  - Modeling paradigms
  - Emerging concepts
  
- Teaching International Operations – from Research to (E)MBA Classroom
  - Concepts from above research
  - Connections to cases

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# GLOBAL SUPPLY CHAIN

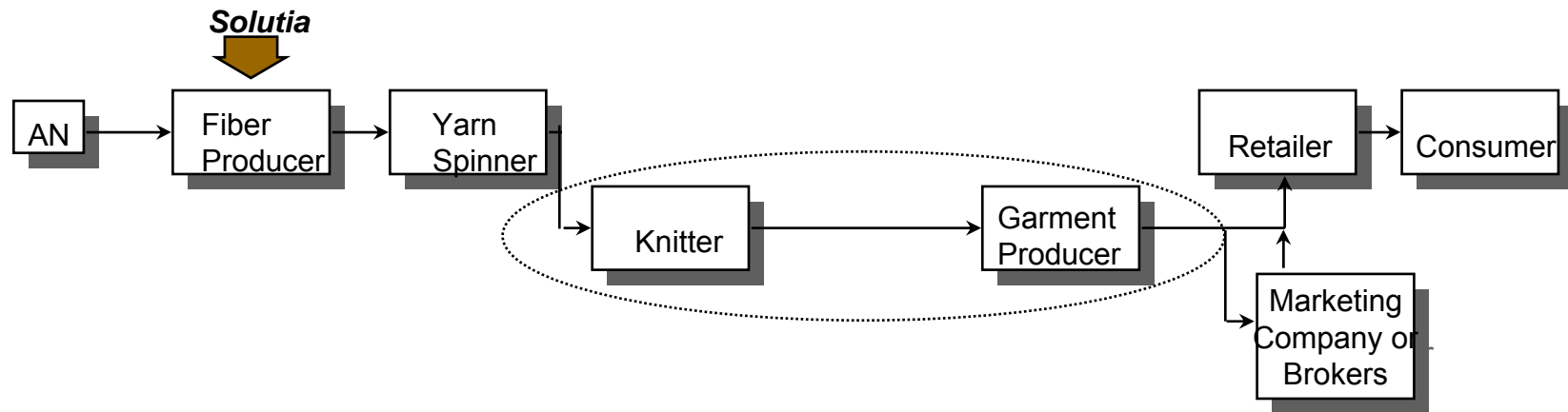
- Integration across three different dimensions



# SOLUTIA, ACRILAN DIVISION: GLOBAL SUPPLY CHAIN COMPETITION IN ACRYLIC FIBERS

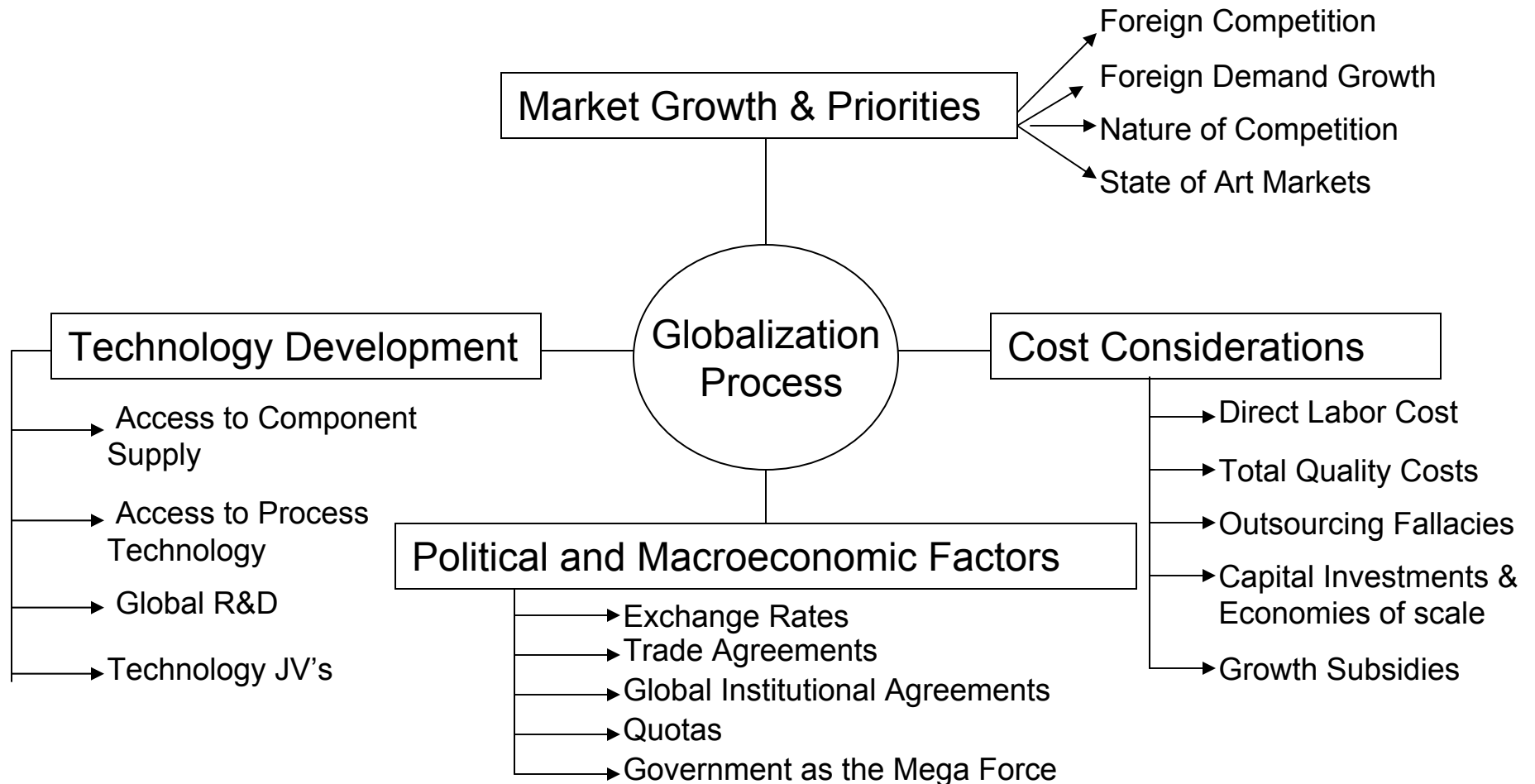
## The Problem:

Acrilan a Solutia (Monsanto spin-off) Division, has historically sold about a third of its fiber into the sweater/single knit market.



Over the years, this market has eroded steadily as Asian finished goods imports have taken share away from the U.S.-based producers. The U.S. sweater producers have not been able to remain cost competitive versus the Asian companies. The U.S. yarn producers are selling less yarn to their U.S. customers as a result, and are facing high cost structures as well. The Asian crisis has accelerated some of these trends.

# WHY DO FIRMS GLOBALIZE THEIR OPERATIONS: A CONCEPTUAL FRAMEWORK



**Reference:** Kouvelis, P. & Niederhoff, J. 2006. "On the globalization of operations and supply chain strategies: A conceptual framework and its application." In: Lee, H.L., Lee, C-Y.(Eds.) Building Supply Excellence in Emerging Economies. Springer, N.Y., Chapter 1, 1-34  
**Global Supply Chain Management**

# PRESENTATION OUTLINE

## ■ Integrated Risk Management In Global Supply Chains

### □ Research

- Operational Hedging ("embedded real options")
- Dynamic Production / Sourcing Strategies & Exchange Rate Uncertainty ("Hysteresis" phenomena)
- Integrated Operational & Financial Hedging

### □ Teaching

- Examples
- Cases: Applichem

## ■ Design & Planning of Global Supply Chain Network

### □ Teaching

- Role of Factories/Conceptual Approach to Design
- Cases: Plant Location Puzzle/ Whelan Pharmaceuticals

### □ Research

- Mathematical Programming Approaches & Decision Support
- Structural Equations Modeling (Global Sensitivity Analysis / Insights)

## ■ Off-shoring & Global (Out) Sourcing Strategies

### □ Research

- Stylized Modeling for Offshoring
- Role of Vertical Integration / Outsourcing for Emerging Markets

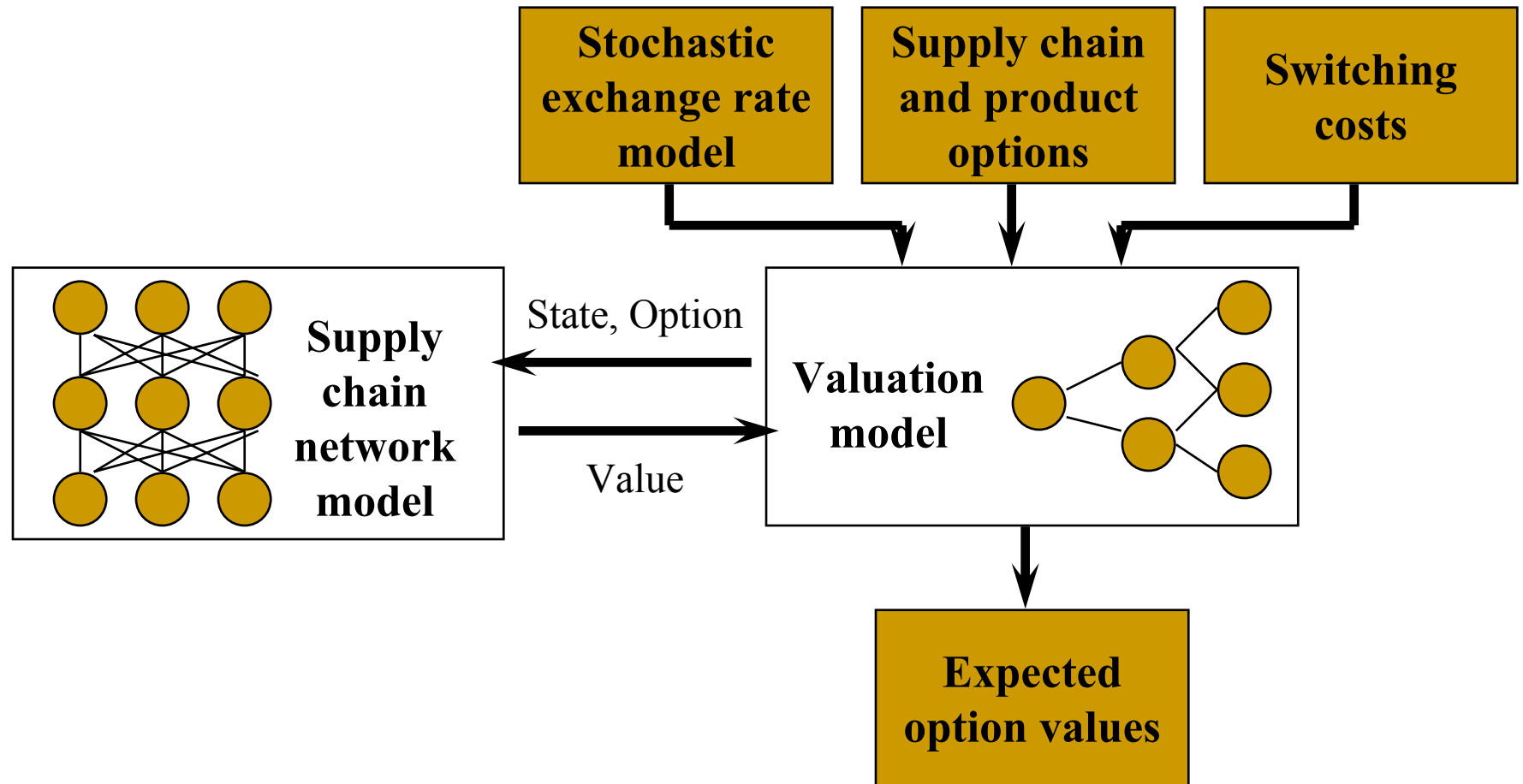
### □ Teaching

- Case: Mattel (toy industry)

## ■ Future Research Directions

# VALUING OPERATIONAL FLEXIBILITY UNDER EXCHANGE RATE RISK

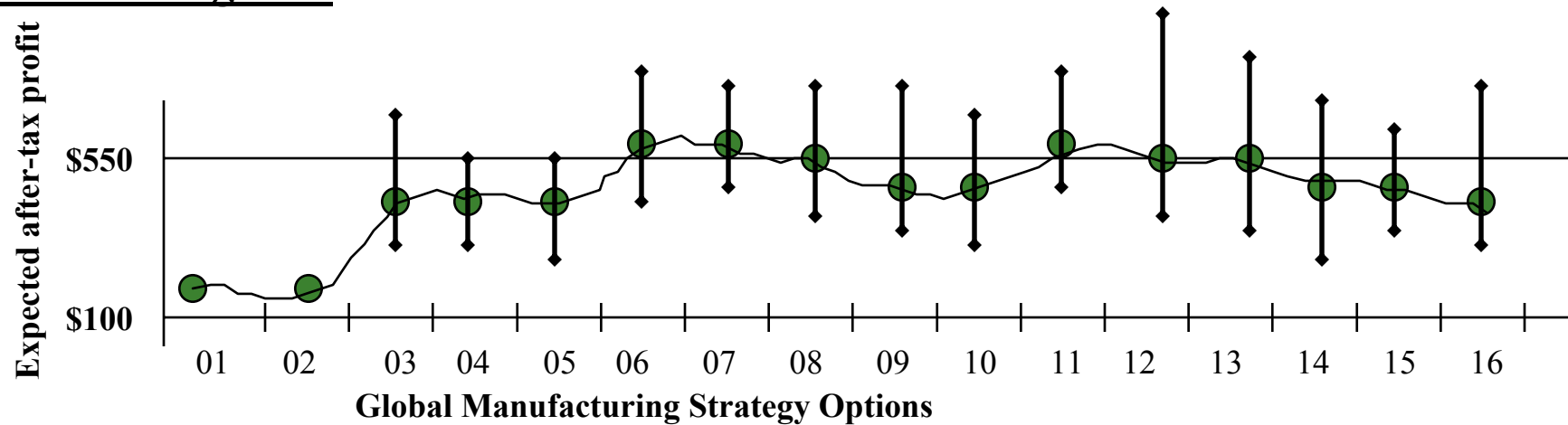
- Modeling framework: Stochastic Dynamic Program for Real Options Valuation



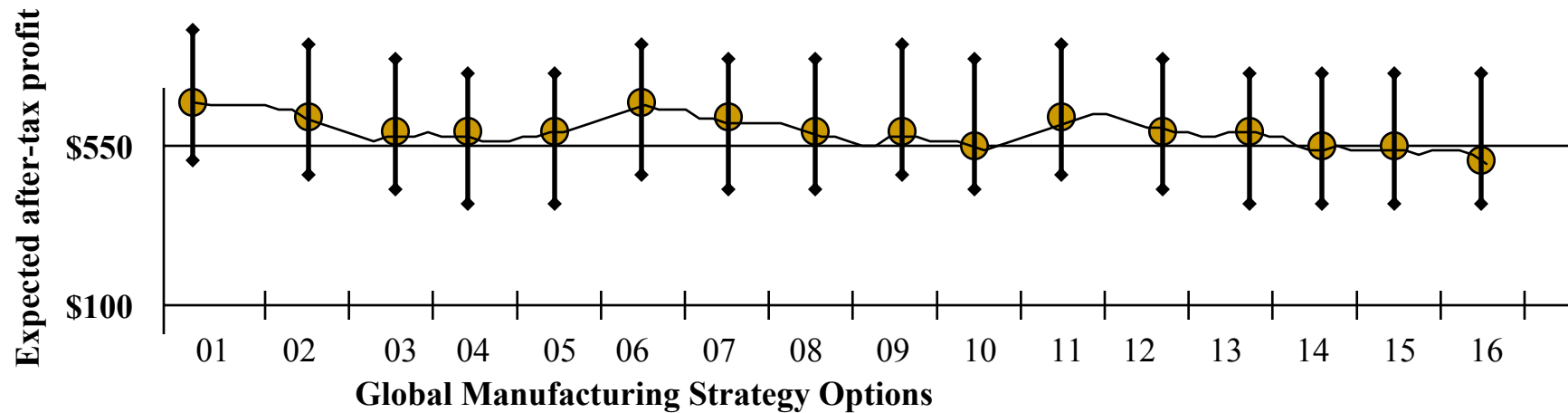
Reference: A. Huchzermeier and M. Cohen, 1996, OR, 44, 1, 100-113

# OPERATIONAL HEDGING

## No-switching case



## Costly switching:



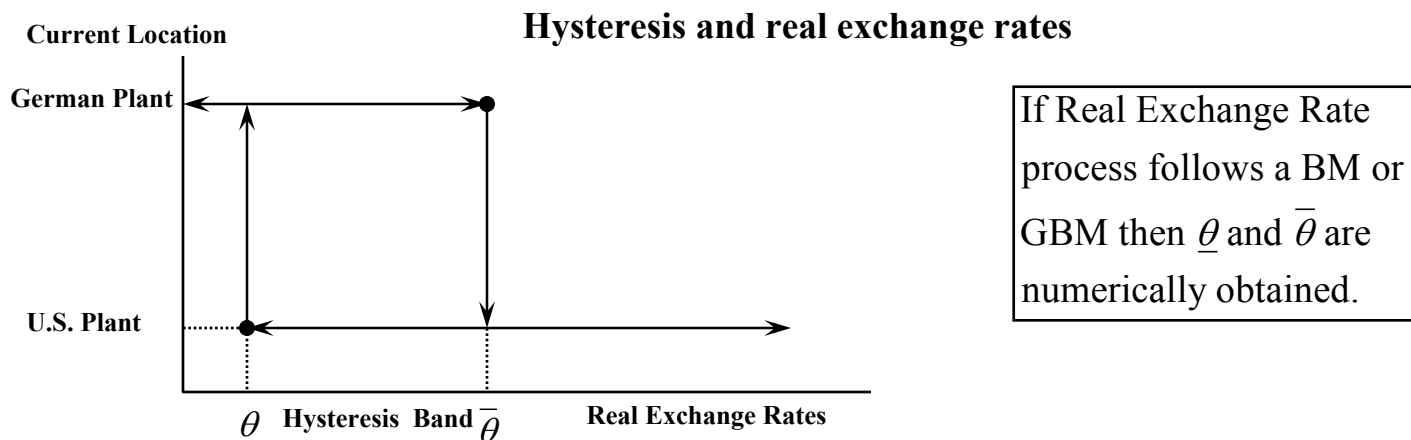
# PRODUCTION SHIFTING STRATEGIES IN A TWO PLANT UN-CAPACITATED NETWORK

## ■ Model

- Configuration: Two plants in different countries
- Uncertainty: Real exchange rates
- Decision: Where to produce the total product demand

$$V(\theta_t, l) = \min_{m \in \{1,2\}} \left\{ \underbrace{-K_{l,m}}_{\text{Switchover Cost for } l \neq m} + \underbrace{SP_m(\theta_t)}_{\text{Single period Production cost}} + \underbrace{\rho E_t V(\theta_{t+1}, m)}_{\text{Discounted future costs}} \right\}$$

- Main result: “Hysteresis (failure of an effect to reverse itself as its underlying cause is reversed)



Reference: B. Kogut and N. Kulatilaka, 1994, MS, 40, 1, 123-139

# PRODUCTION SHIFTING STRATEGIES IN A TWO PLANT CAPACITATED NETWORK

## ■ Model

- Configuration : Two plants in different countries, capacitated situation  
(Capacities  $K_1 + K_2 = D + S$ )
- Uncertainty : Real exchange rates
- Decision : How to allocate excess capacity

$$V(\theta, y) = \min_{0 \leq x \leq S} \{ \phi(\theta, x) + \delta(y, x) + \rho EV(\theta', x) \}$$

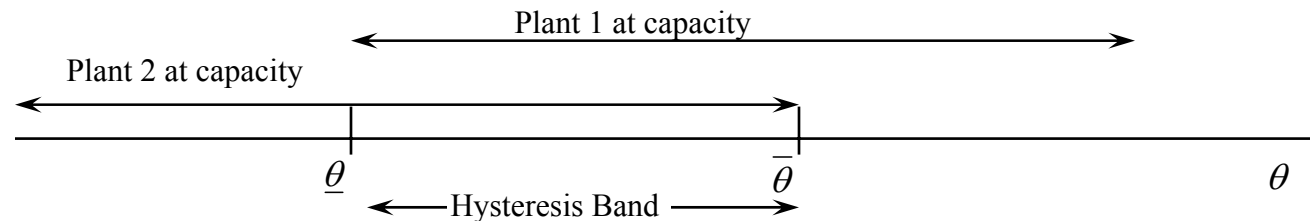
switchover cost assumption:  $\delta(y, x) = \Delta |x - y|$  or  $\delta(x, y) = \Delta$

operating cost definition:  $\phi(\theta, x) = c_1(\theta, K_1 - S + x) + c_2(\theta, K_2 - x)$

# PRODUCTION SHIFTING STRATEGIES IN A TWO PLANT CAPACITATED NETWORK (CONT.)

## ■ Main results

- Case of concave production costs
  - Capacity allocation: Do nothing ( $x^* = y$ ) or extreme point ( $x^* = 0, x^* = S$ )
- Timing of switching: “Hysteresis” (between 0 and S)

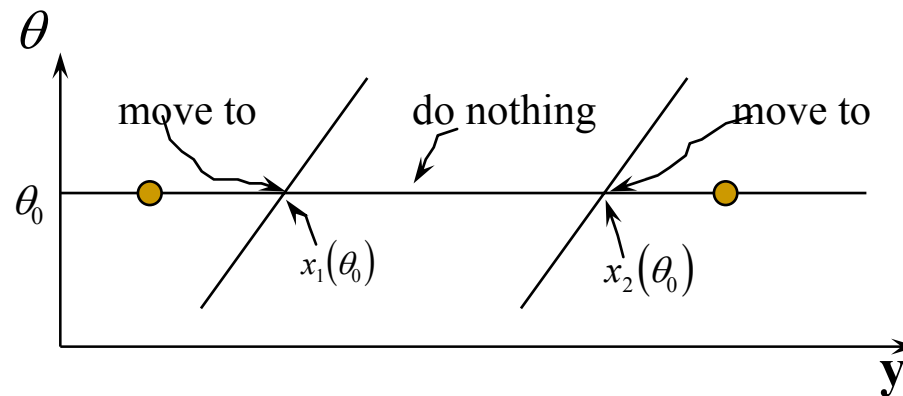


- **The Hysteresis band increases as:**
  - Exchange rate uncertainty **increases**
  - Switchover costs **increase**

# PRODUCTION SHIFTING STRATEGIES IN A TWO PLANT CAPACITATED NETWORK (CONT.)

- Main results
  - Case of convex production costs and linear switchover costs
    - Capacity allocation

$$x^*(\theta, y) = \begin{cases} x_1(\theta) & 0 \leq y \leq x_1(\theta) \\ y & x_1(\theta) \leq y \leq x_2(\theta) \\ x_2(\theta) & x_2(\theta) \leq y \leq S \end{cases}$$

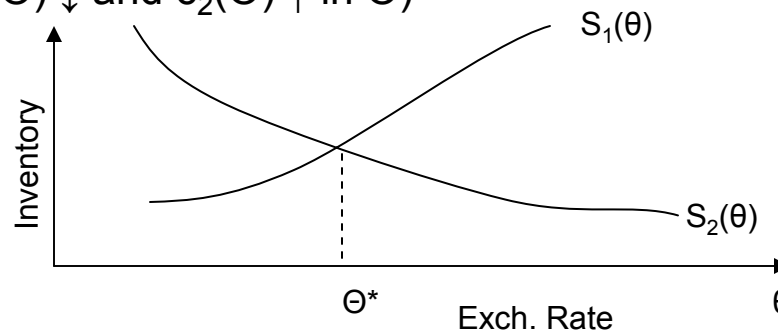


# OPTIMAL OPERATING POLICIES FOR MULTI-PLANT STOCHASTIC MANUFACTURING SYSTEMS

- Issues modeled
  - Congestion & delay through demand and processing time uncertainties
  - Exchange rate uncertainty
  - Allowing production to stock (inventories)
- Production facilities in two countries
  - Demand  $\sim$  Poisson ( $\lambda$ )
  - Proc. Time Facility  $\sim$  Exponential ( $\mu_i^{-1}$ )
  - $\Theta$  = exchange rate
  - $c_i(\Theta)$  = per unit cost facility  $i$  ( $c_1(\Theta) \downarrow$  and  $c_2(\Theta) \uparrow$  in  $\Theta$ )

- Optimal Policy: Barrier type

Plant operated for inventory level < barrier

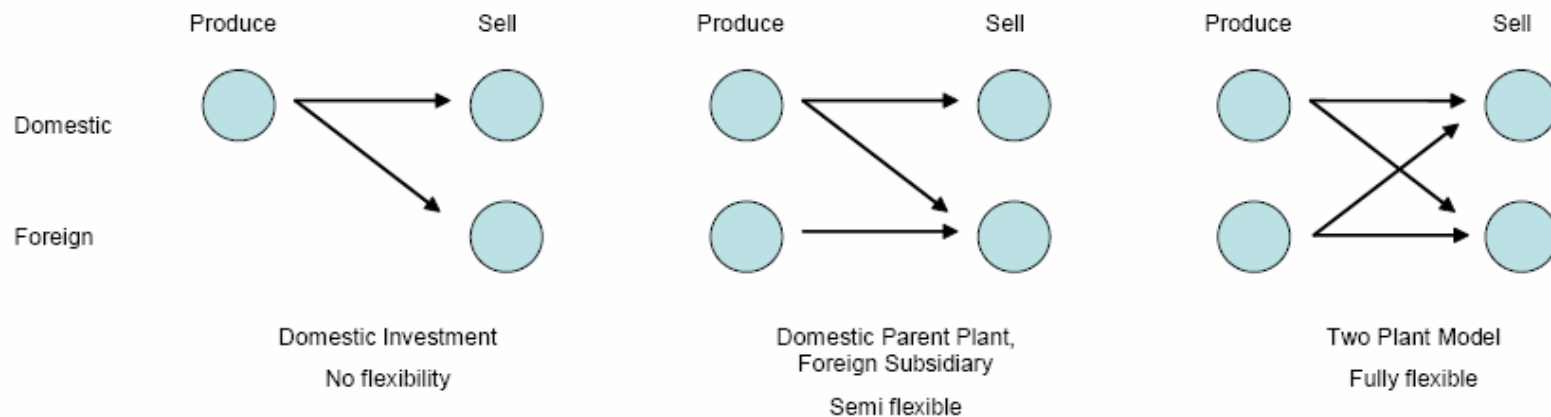


- Primary / Secondary plant role
- Inventory as a hedge: when one plant significantly cheaper than the other

**Reference:** L. Li, E. Porteus, H. Zhang (2001) "Optimal Operating Policies for Multi-Plant Stochastic Manufacturing Systems in a changing environment", MS 47, 11, 1539-1551

# OPTIMAL POLICIES WITH UNRELIABLE SUPPLIERS AND CURRENCY EXCHANGE RISKS

## Capacity Alternatives



Reference: Aytikin/Birge – Supplier and Exchange Risk”

# VALUE CALCULATIONS

No Flexibility:

$$V_{noflex} = E\left[\int_0^{\infty} e^{-rt}((s_1 - c_1)d_1 + (s_2 Y_t - c_1)d_2)Z_t^1 dt\right]$$

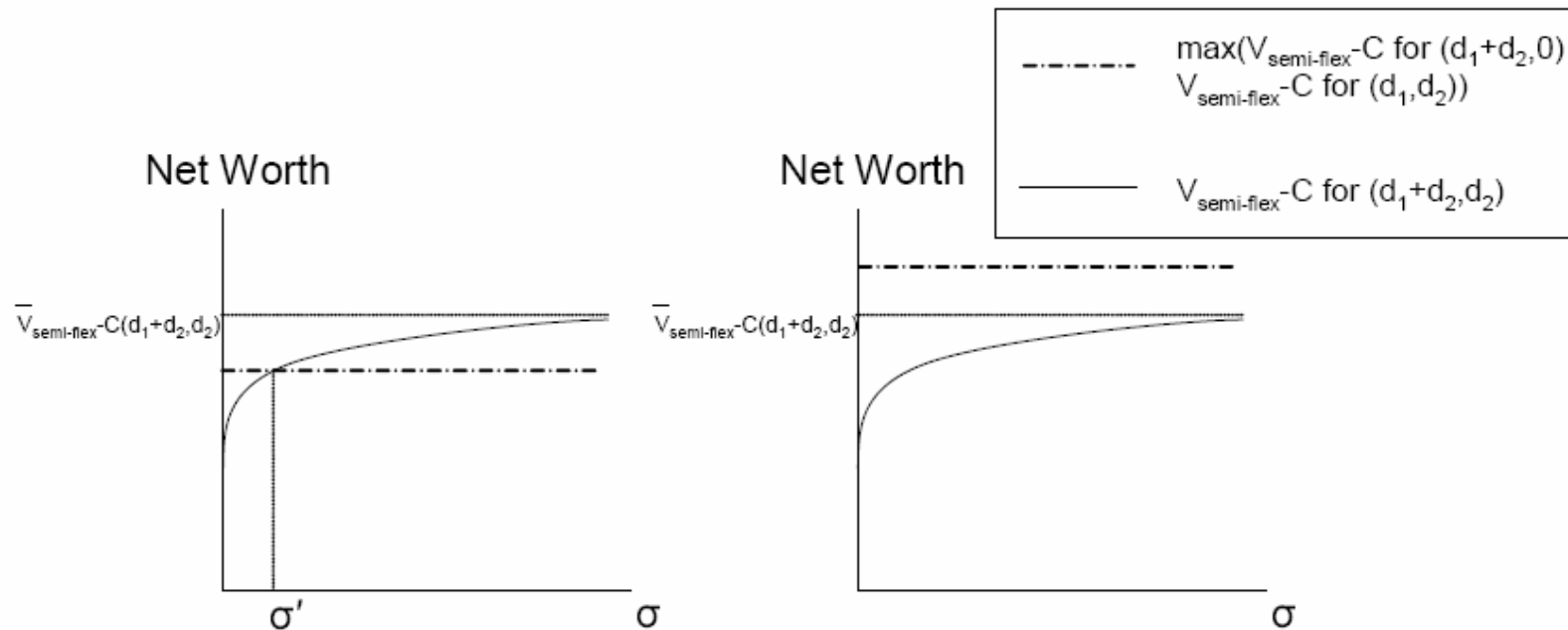
Semi-flexibility ( $k_1 \geq d_1 + d_2$ ):

Instantaneous cash flow:

$$p(t) = (s_1 - c_1)d_1 Z_t^1 + \max(d_2(s_2 Y_t - c_1)Z_t^1, (d_2 - k_2)(s_2 Y_t - c_1)Z_t^1 + k_2 Y_t(s_2 - c_2)Z_t^2)$$

$$\begin{aligned} V_{semi-flex}(\vec{k}) &= E\left[\int_0^{\infty} e^{-rt} p(t) dt\right] \\ &= E\left[\int_0^{\infty} e^{-rt} \left( (s_1 - c_1)d_1 + d_2(s_2 Y_t - c_1) \right) Z_t^1 \right. \\ &\quad \left. + k_2 c_2 \max\left(0, \left(\frac{c_1}{c_2} - Y_t\right) Z_t^2\right) dt\right] \end{aligned}$$

# VOLATILITY EFFECT



Reference: Aytekin/Birge – Supplier and Exchange Risk”

# OWNERSHIP STRATEGIES OF PRODUCTION FACILITIES SUPPLYING FOREIGN MARKETS

## ■ Main tradeoffs

<b>Production Strategy</b>	<b>Control</b>	<b>Resource Commitment</b>	<b>Dissemination Risk</b>
<b>EXP</b>	<b>High</b>	<b>Low</b>	<b>Low</b>
<b>JV</b>	<b>Medium</b>	<b>Medium</b>	<b>High</b>
<b>WOS</b>	<b>High</b>	<b>High</b>	<b>Low</b>

- Effect of real exchange rates on the long term ownership strategies of production facilities in foreign markets
  - P.Kouvelis, K.Axarloglou and V.Sinha, 2001, “Exchange rates and the choice of ownership structure of production facilities” MS, 47(8), 1063-1080

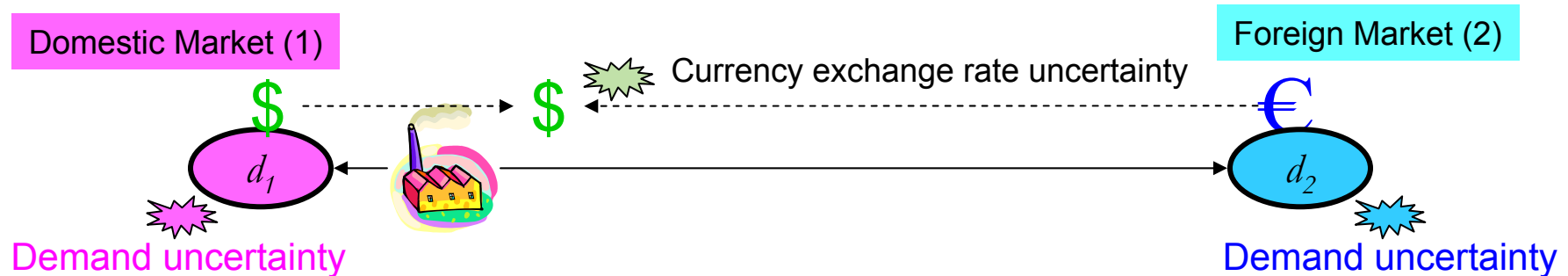
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# RESULTS

- Hypothesis 1:
  - The WOS production strategy is preferred over the JV strategy when the domestic currency is appreciated with respect to the foreign currency
- Hypothesis 2:
  - The WOS strategy is preferred over the EXP strategy when the domestic currency is appreciated with respect to the foreign currency
- Hypothesis 3:
  - The “Hysteresis Band” expands as the volatility of the exchange rate increases
- Hypothesis 4:
  - Less competitive industries imply a wider “Hysteresis Band”
- Hypothesis 5:
  - The “Hysteresis Band” is narrower for industries in markets of high demand.

# TWO RESEARCH PROJECTS ON INTEGRATED RISK MANAGEMENT

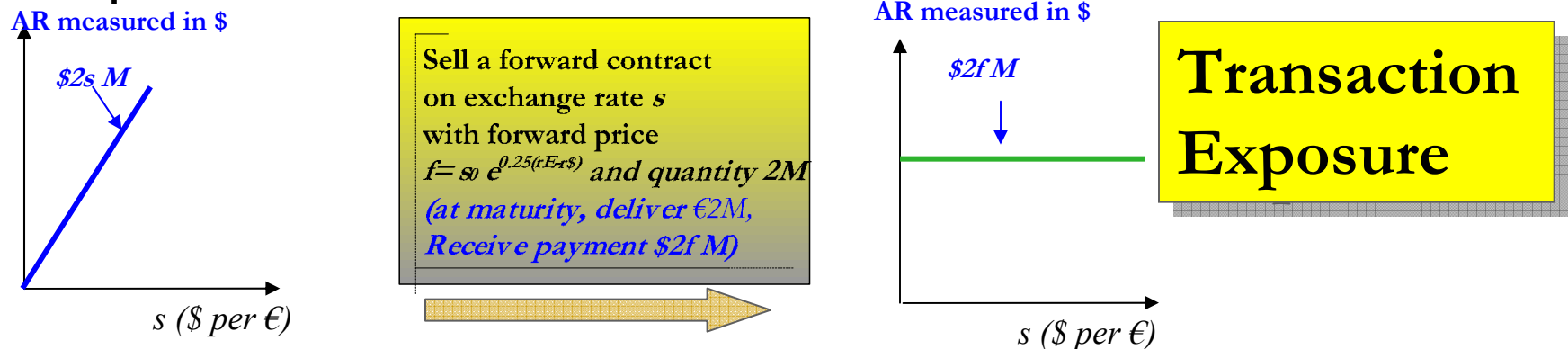
Take the perspective of a global firm who sells to both domestic and foreign markets



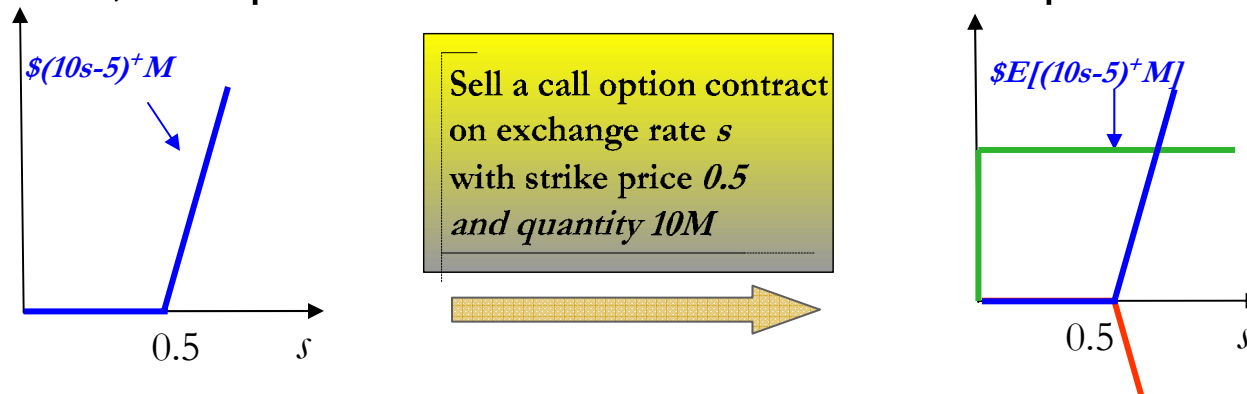
- Paper #1: Ding, Q., **L. Dong**, and **P. Kouvelis** (2004), “On the **Integration** of Production and Financial Hedging Decisions in Global Markets,” forthcoming in *Operations Research*.
- Paper #2: **Dong, L.**, **P. Kouvelis**, and P. Su (2006), “Operational Hedging Strategies and **Competitive Exposure** to Exchange Rates.”

# HOW DOES FINANCIAL HEDGING WORK?

- Example I: An US firm has account receivable of €2M in 3 months



- Example II: An US firm produces in US and sells in Europe 1M units in 3 months, with production cost \$5/unit and sales price €10/unit

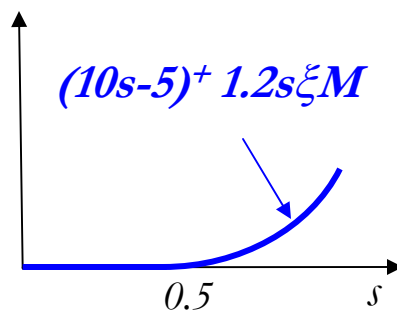


# WHEN DOESN'T FINANCIAL HEDGING WORK WELL?

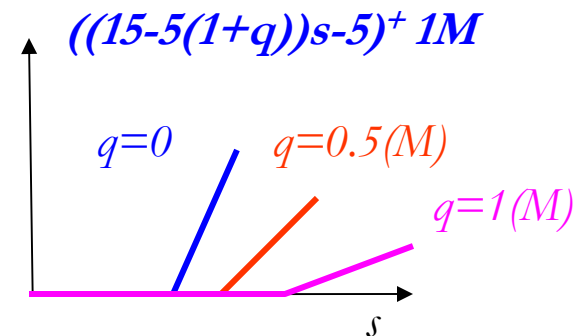
## Operational/Competitive Exposure

- Example I: An US firm produces in US and sells in Europe 1M units in 3 months, with production cost \$5/unit and sales price €10/unit

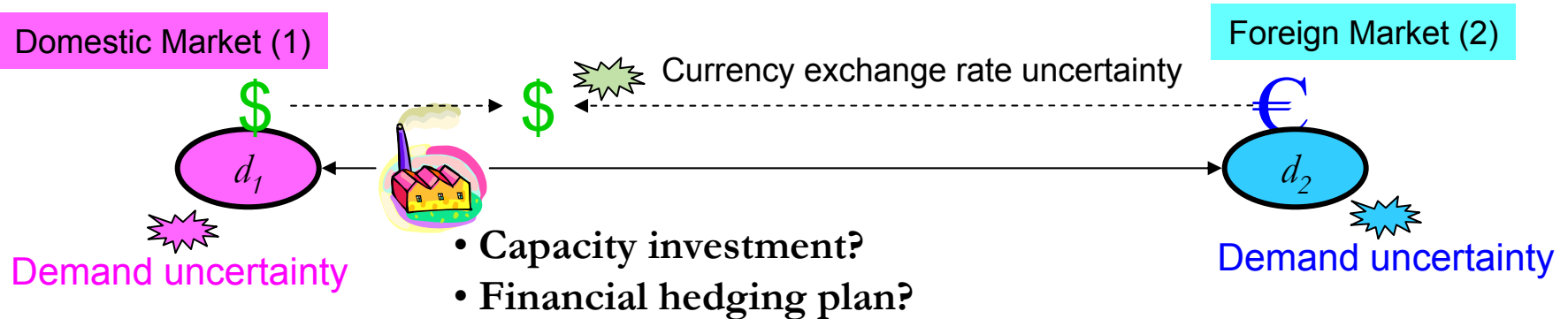
- Uncertain sale quantity, partially correlated to the exchange rate,  $sales = 1.2s\xi M$  units,  $\xi$  is random



- Competitor's committed quantity  $q$  is unclear in the European market, *market clearing price*  $= 15 - 5(1+q)$ ,



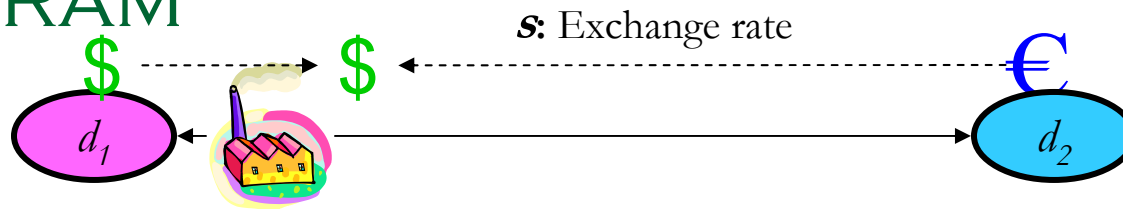
# PAPER # 1: INTEGRATION OF OPERATIONAL & FINANCIAL POLICIES



## Research Questions:

1. What is the optimal integrated operational and financial policy to maximize firm's utility?
2. Effects of operational hedge and financial hedge on capacity decision and firm's performance

# MODEL – TWO STAGE STOCHASTIC PROGRAM



**Time 0**

**Information:** Time 1 demand and currency exchange rate **distributions**

**Decisions:** Capacity  $X \Rightarrow$  Capacity reservation cost  $C(X)$

Financial contracts  $h \Rightarrow$  financial contracts cost  $H(h)$

**Time 1**

**Information:** Realizations of demand and currency exchange rate

**Decisions:** Recourse decisions to maximize operations profit  $\pi^{op}(X, s, d)$ ,  
exercise  $h$  to maximize the payoff of financial contract  $R(s, h)$

**Effective time 1 profit**

$$\pi(X, h, s, d) = (-C(X) - H(h))e^{\gamma} + \pi^{op}(X, s, d) + R(s, h)$$

$\gamma$  is the risk-free interest rate

# CLOSE LINKAGE BETWEEN FINANCIAL HEDGING AND REAL OPTIONS IN OPERATIONS

- If  $\pi^{op}$  can be written as profit from a portfolio of real options,

i.e.,

$$\pi^{op}(X, s, \overset{I}{d}) = \sum_{i=1}^n a_i(X, \overset{I}{d})(s - S_i^C)^+ + \sum_{i=1}^m b_i(X, \overset{I}{d})(S_i^P - s)^+ + c(X, \overset{I}{d})$$

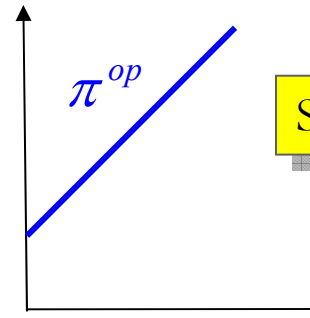
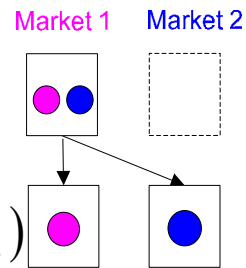
and  $\overset{I}{d}$  and  $s$  are independent, then the **optimal financial hedging policy** is a portfolio of call options  $(S_i^C, \mathbb{E}[a_i(X, \overset{I}{d})])_{i=1}^n$  and a portfolio of put options  $(S_i^P, \mathbb{E}[b_i(X, \overset{I}{d})])_{i=1}^m$ .

# EXAMPLES OF OPTIMAL FINANCIAL HEDGE

- No Postponement

$$\pi^{op}(X, s, d_1^1)$$

$$= p_1 \min(X_1, d_1) + sp_2 \min(X_2, d_2)$$



Sell a forward contract

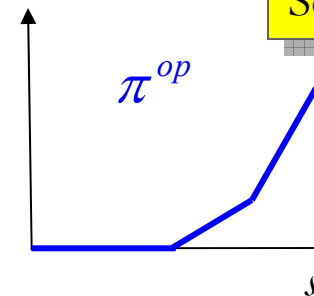
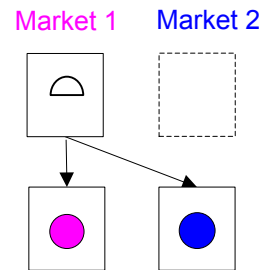
- Postponement with capacity pooling

$$\pi^{op}(X, s, d_1, d_2)$$

$$= r_2^+(s) \min((X - d_1)^+, d_2)$$

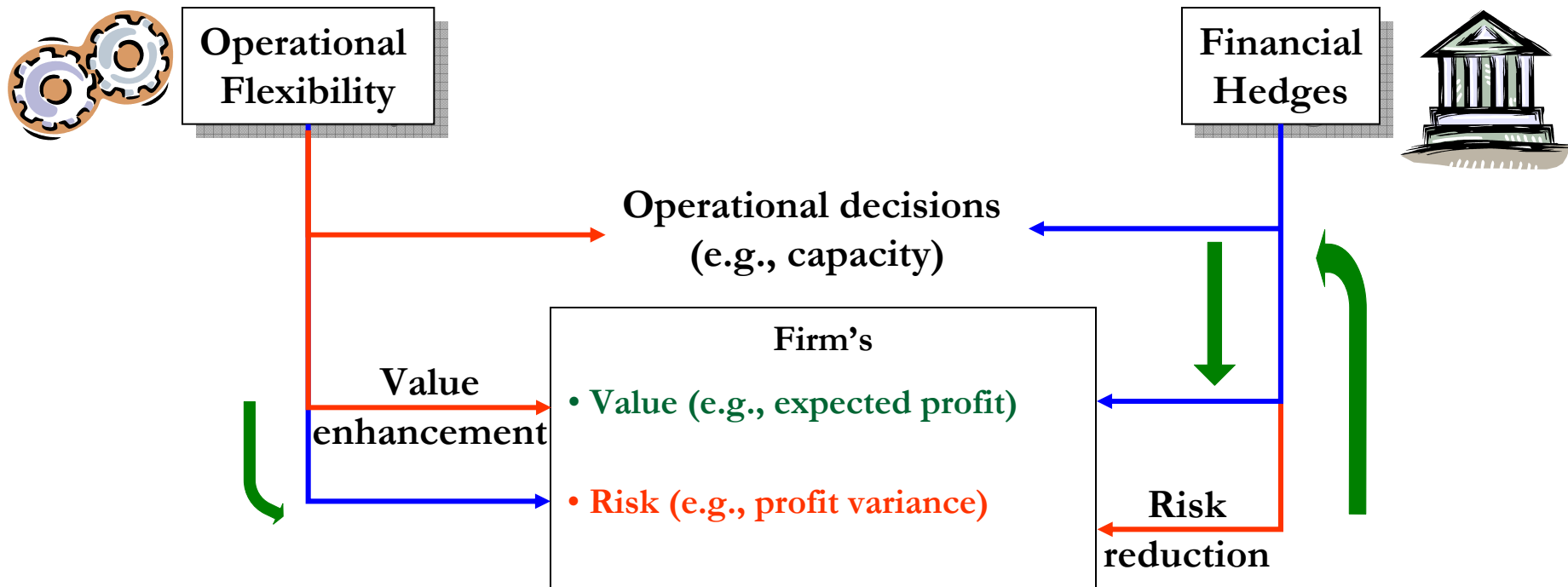
$$+ (r_2(s) - r_1^+) (\min(X, d_2) - \min((X - d_1)^+, d_2))$$

$$+ r_1 \min(X, d_1)$$



Sell two call options

# PAPER # 1 INSIGHTS



- Capacity decisions of firms using financial hedge are less sensitive to volatilities in exchange rate, demand, and risk attitude
- The use, or lack of use of financial hedge can alter **global supply chain structural choices**, such as the desired location and number of production facilities to be employed to meet global demand

# THE GLOBAL MANUFACTURER'S DILEMMA

- Suppose we can produce in U.S. or Europe
- Demand and currency rates may vary
- Where to put production capacity?
- How much to produce in each country?
- Should we use currency futures (or other options



**Example:** John Birge's presentation

# GLOBAL MANUFACTURER DETAILS

- Suppose high demand in U.S. vs.. Europe means higher U.S.\$ value per Euro
- High U.S. demand 100k, Euro is 50k, and \$1/Euro
- Low U.S. demand 50k, Euro is 100k, and \$2/Euro
- Sell for 20k E or \$ in each region
- Cost is 10k E or \$ in each region
- How to hedge? Futures?



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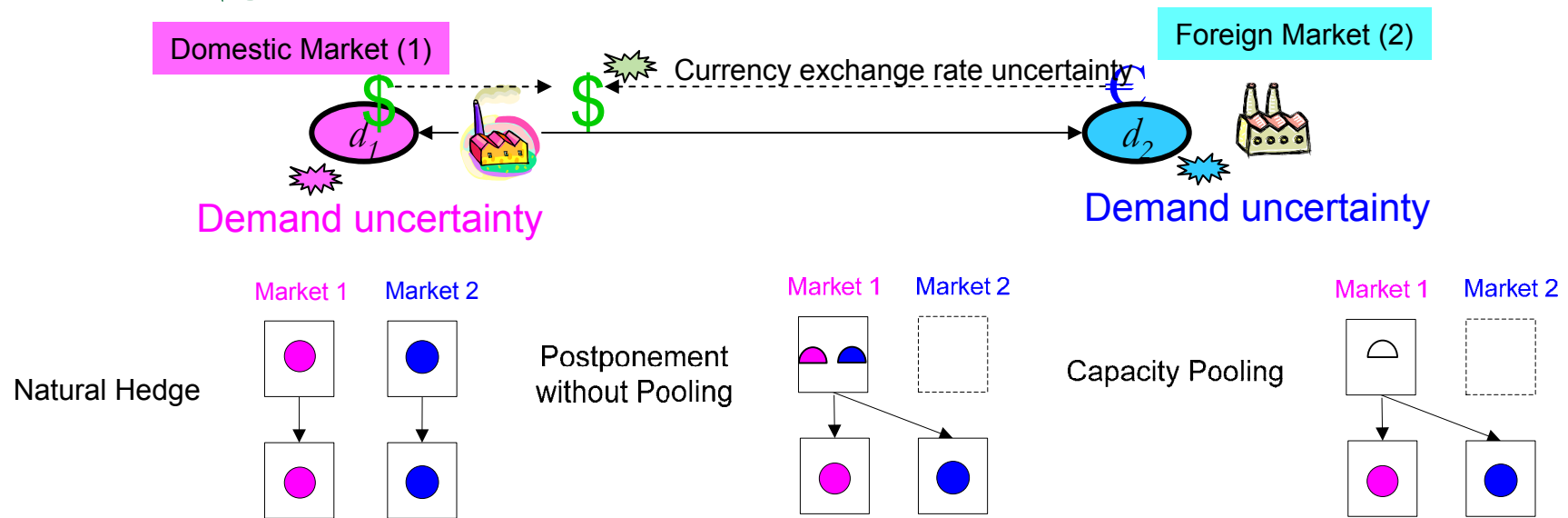
# MANUFACTURER AND FUTURES: DO NATURAL HEDGES & FUTURES WORK?

- Suppose produce and sell in each country (“natural hedge”)
- Use futures to guarantee value in \$
- Sell 500M Euro in future for \$1.50 (expectation)
  - $\$750M = (50k \text{ sales})(10k \text{ E margin})(\$1.5/E)$
- Return:
  - Guaranteed \$750M
  - High U.S.: \$1000M (1/2 prob.)
  - Low U.S.: \$1500M (1/2 prob. 500U.S. plus 1B E)
  - EXPECTATION: \$2000M

# USING OPERATIONAL HEDGES IN PLACE OF FINANCIAL

- Suppose we just produce in Europe when U.S. demand is high and just in U.S when U.S. demand is low
- Result:
  - U.S. demand high:
    - Sales: \$2000M in U.S. + \$1000M in Europe
    - Cost: \$1500M in Europe
    - Net:  $3000 - 1500 = \$1500\text{M}$
  - U.S. demand low:
    - \$1000M in U.S. + \$4000M in Europe - \$1500M in U.S.
    - Net:  $5000 - 1500 = \$3500\text{M}$
  - Expectation: \$2500M!! ( $\gg$  \$2000M with financial hedging)

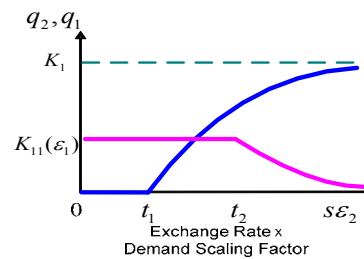
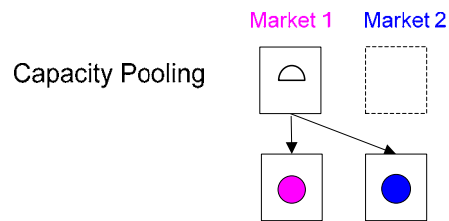
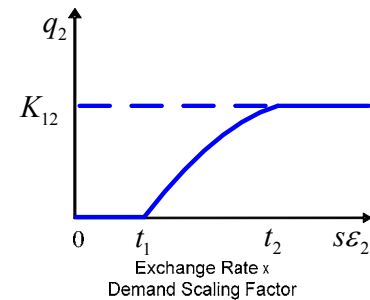
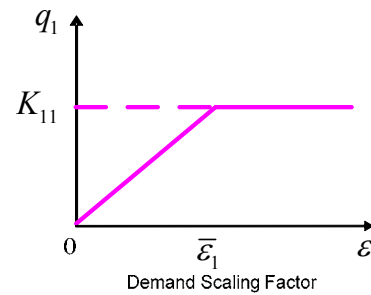
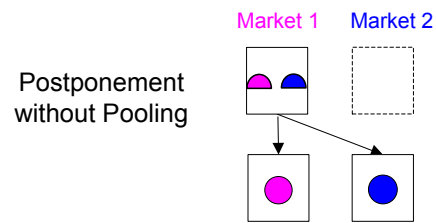
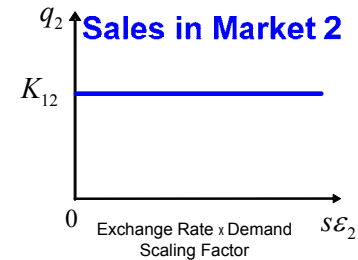
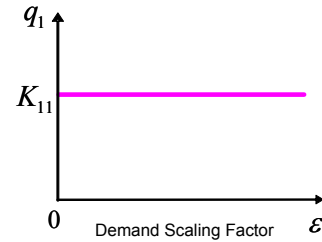
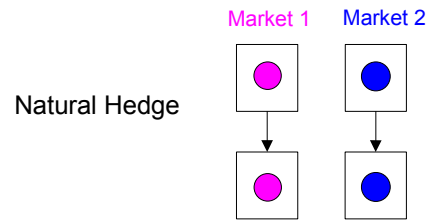
# PAPER #2: OPERATIONAL HEDGE AND COMPETITIVE EXPOSURE TO EXCHANGE RATES



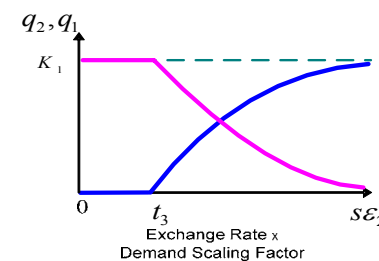
## Research Questions:

1. What are the effects on the global firm's *capacity strategy* in response to the competitive exposure?
2. How do *operational flexibilities* affect firms' *profits and risks* associated with exposure to fluctuating exchange rates?

# OPERATIONAL FLEXIBILITY EXPLOITS FAVORABLE EXCHANGE RATE REALIZATIONS



Low Demand Scenario in Domestic Market 1



High Demand Scenario in Domestic Market 1

# EFFECT OF GLOBAL FIRM'S OPERATIONAL FLEXIBILITY

	Global Firm			Local Incumbent	
	Optimal capacity	Expected profit	Downside risk (VaR, EDR)	Expected profit	Downside risk (VaR, EDR)
Effect of ↑ <b>op. flexibility</b>	~	↑	↓	~	↑
Effect of ↑ <b>exchange rate volatility</b>	↑(under op. flex.)	↑(under op. flex., fastest under capacity pooling)	↑ (slowest under capacity pooling)	↑ (under op. flex.)	↑(under op. flex.)
Effect of ↑ <b>capacity in foreign mkt.</b>	Non-monotone	↓(decreases in exchange rate volatility)	Non-monotone	Non-monotone	Non-monotone

# APPLICHEM CASE STUDY: OPERATIONAL FLEXIBILITY AND EXCHANGE RATE

From/To	Mexico	Canada	Venezuela	Germany	US	Japan	Tot. Prod		Capacity
Mexico	3.00	0.00	0.00	0.00	3.20	0.00	6.20	<=	22.00
Canada	0.00	2.60	0.00	0.00	1.10	0.00	3.70	<=	3.70
Venezuela	0.00	0.00	4.50	0.00	0.00	0.00	4.50	<=	4.50
Germany	0.00	0.00	11.50	20.00	3.60	11.90	47.00	<=	47.00
US	0.00	0.00	0.00	0.00	18.50	0.00	18.50	<=	18.50
Japan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<=	5.00
Tot. Sale	3.00	2.60	16.00	20.00	26.40	11.90			
Demand	=	=	=	=	=	=			

TABLE 4 Optimal Distribution Logistics Schedule (Million lbs)

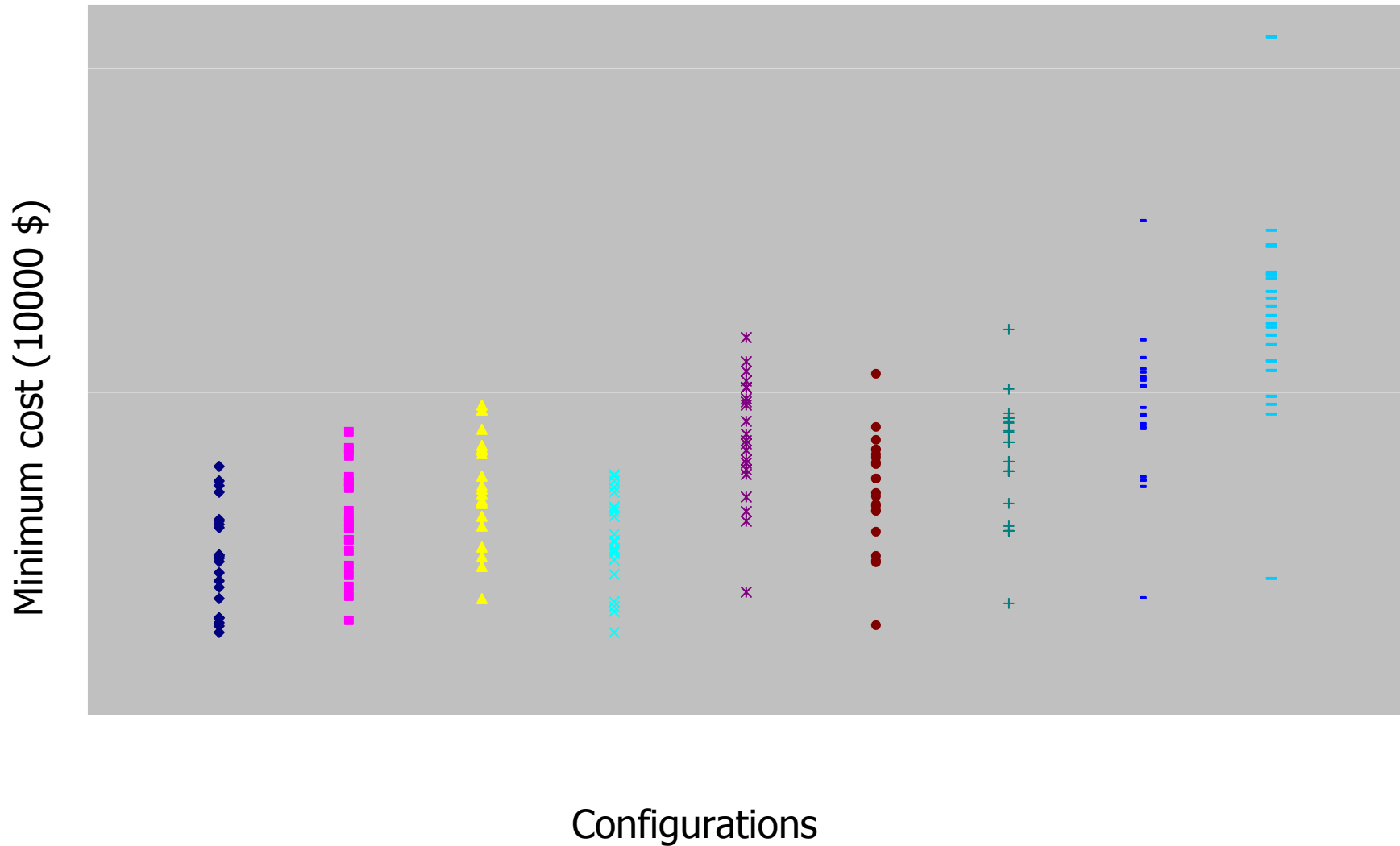
- Minimum Cost: \$73.9 million
- Configuration Changes:  
Sunchem(Japan) should be closed, with Frankfurt plant supplies its needs

# SCENARIO-BASED APPROACH

- A *configuration* is defined by a set of production capacities in various countries.
- Possible plant configurations for Applichem to satisfy worldwide demand:

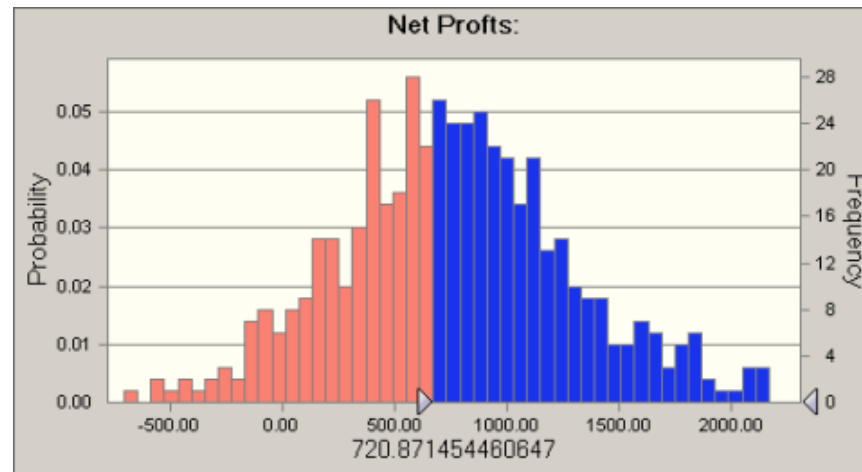
ID	Total capacity	Plants closed
C1	100.7	None
C2	97	Canada
C3	96.2	Venezuela
C4	95.7	Sunchem
C5	92.5	Canada & Venezuela
C6	92	Canada & Sunchem
C7	91.2	Venezuela & Sunchem
C8	87.5	Canada, Venezuela & Sunchem
C9	82.2	Gary

# MINIMUM 1994 COST FOR EACH HISTORICAL SCENARIO/CONFIGURATION

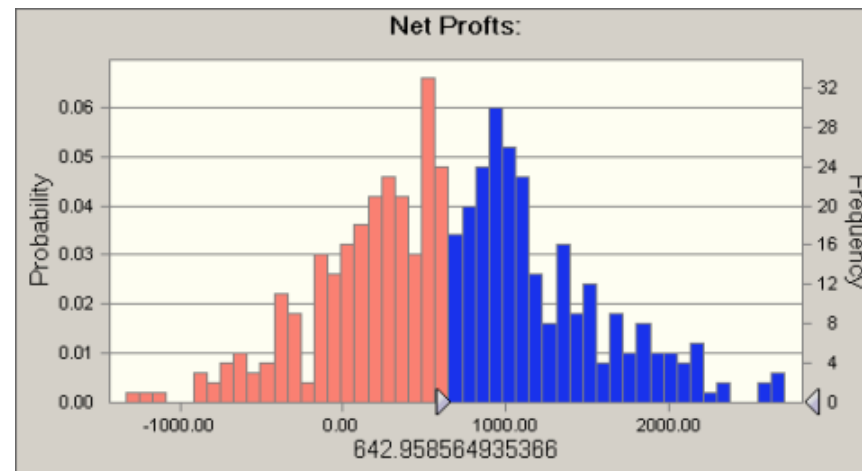


# OPTION VALUE OF STOCHASTIC RECOURSE

- Keep all plants open except Japanese plant
- Certainty level is 49.84% from 747.72 to 2500
- $\mu=760.31$ ;  $\sigma=523.05$



- Close Canada, Japanese and Venezuela plants
- Certainty level is 45.98% from 747.72 to 2500
- $\mu=689.33$ ;  $\sigma=720.97$



Option Value increases with the number of open plants



# PRESENTATION OUTLINE

## ■ Integrated Risk Management In Global Supply Chains

- Research
  - Operational Hedging (“embedded real options”)
  - Dynamic Production / Sourcing Strategies & Exchange Rate Uncertainty (“Hysteresis” phenomena)
  - Integrated Operational & Financial Hedging
- Teaching
  - Examples
  - Cases: Applichem

## ■ Design & Planning of Global Supply Chain Network

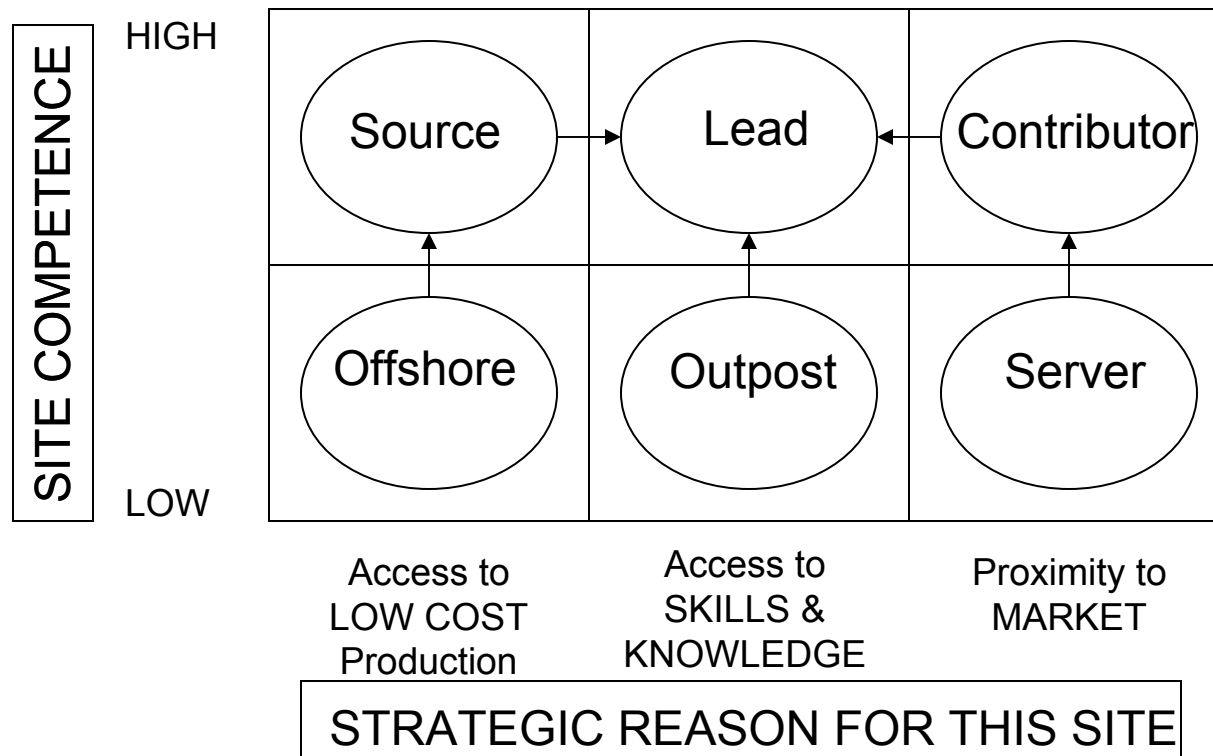
- Teaching
  - Role of Factories/Conceptual Approach to Design
  - Case: Plant Location Puzzle
- Research
  - Mathematical Programming Approaches & Decision Support
  - Structural Equations Modeling (Global Sensitivity Analysis / Insights)

## ■ Global (Out)Sourcing Strategies

- Research
  - Stylized Modeling for Offshoring
  - Role of Vertical Integration / Outsourcing for Emerging Markets
- Teaching
  - Case: Mattel (toy industry)

## ■ Future Research Directions

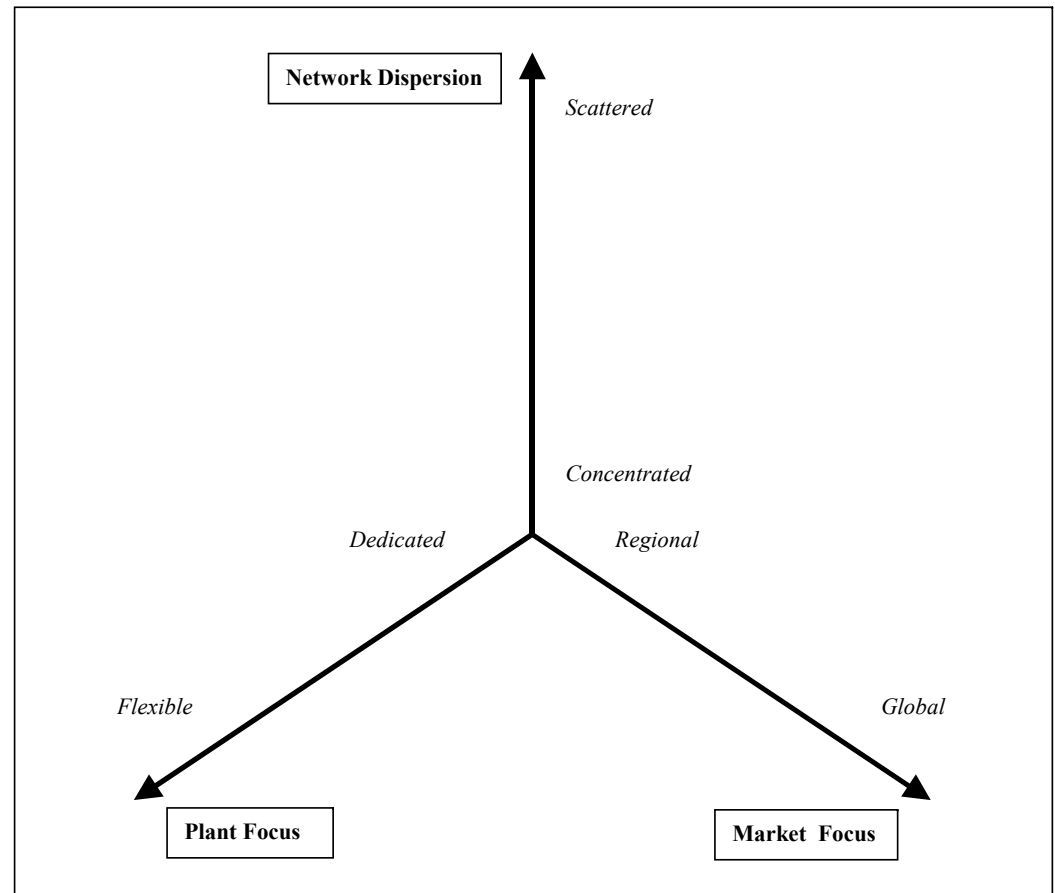
# THE ROLE OF FOREIGN FACTORIES – A STRATEGIC MATRIX



Reference: Ferdows, K. 1997. "Making the most of Foreign Factories", HBR

# CONCEPTUAL FRAMEWORK

1. Market focus
2. Plant focus
3. Network dispersion



**Reference:** Kouvelis, P., Munson, C. 2004 "Using a structural equation modeling approach to design and monitor strategic international facility networks" In: Simchi-Levi, D-Wu, S.D., Shen, S-Z(Eds). Handbook of Quantitative Supply Chain Analysis. Kluwer, 681-709  
**Global Supply Chain Management**

# PLANT LOCATION PUZZLE (HBR MINI-CASE)

Case Situation: Our Company ELDORA (EDC)

- Bicycle Manufacturer
- 30% Market Share in the US
- Saturation of US Market
- ... < 2% growth
- Expansive growth in Asian Markets
- ...sales doubling
- EDC considers Global expansion
- ...with an eye towards Asian markets
- Among Expansion Alternatives Considered:
  - Enter China via sales company
  - ...outsource production
  - Greenfield plant investment
  - ...but where? China? Taiwan? Singapore?

---

# DESIGN OF GLOBAL SUPPLY CHAIN NETWORKS

- Critical issues for a global firm
  - Duties
  - Differing tax rates
  - Government financing incentives
  - Exchange rates
  - Local content
  - Offset trade
  - Quotas
  - Transfer prices
  - Direct export incentives
  - Ownership structure of facilities

# THE DEC PROBLEM AND MODEL

A word description of the cost-only **DEC** model is:

- Minimize :
  - Fixed and variable production + distribution + inventory + taxes + net duty + procurement from vendors
- Subject to:
  - Demand is met
  - “Conservation” of product flow
  - Production limitations
  - Inventory limitations
  - Distribution limitations
  - Local content restrictions
  - “Conservation” of duty credits
  - Style limitations
  - Facility use limitations

**Reference:** Amtzen, B. C., et. Al, 1995 “Global Supply Chain Management at Digital Equipment Corporation”, Interfaces 25, 1, 69-93

# DEVELOPMENT OF INTERNATIONAL FACILITY NETWORKS WITH FINANCING TRADE TARIFF AND TAX CONSIDERATIONS

## ■ **Model structure**

- Deterministic model
- Two facility levels: Component plants and DCs (assembly and distribution)
- Location and production allocation decision
- Objective after-tax profit maximization

## ■ **Some results**

- Trade tariffs increase --> decentralization of distribution network
- Differential tax rates --> more centralized Mfg. and distribution network
- Regional trading zones (with inexpensive component transportation) --> “regionalization” effect on facility network (decentralized over trading zones, centralized within each zone)
- Increases in local or regional content requirement
  - --> if reasonable, attract investment in the country or zone
  - --> if too high, opposite effect (complete facility withdrawal)

**Reference:** Kouvelis, P., Rosenblatt, M. J., Munson C. 2004. “A Mathematical Programming Model to Global Plant Location Problems: Analysis and insights”, IIE Transactions 36(92), 127-144

# STRUCTURAL EQUATIONS MODELING FOR DESIGNING AND MONITORING STRATEGIC INTL. FACILITY NETWORKS

**Formulate complex MIPs----- see below**

**Maximize Net Present Value of:**

[Revenue from units & subassemblies produced

*minus* (variable production costs & cost of goods sold + annual fixed costs of a DCs & subassembly plants + transportation costs + loan interest payment + depreciation)

*plus* (loan interest payment + depreciation)

*minus* (loan payment + income taxes)]

*minus* cash expenditures in fixed assets in year 0 not financed by external sources

**Subject to:**

- 1) Demand Constraints
- 2) Subassembly Line Capacity
- 3) Plant Capacity
- 4) DC Capacity
- 5) Conservation of Subassembly Flows
- 6) Loan Ceilings
- 7) Nonnegative Profit in Each Country
- 8) Count # of Different Subassemblies Produced at Each Plant
- 9) Non-negativity & Binary Constraints

***Finally get specific solutions to very specific data sets***

***But no managerial insights for a fast changing environment ( product mix, labor inputs, technologies, governmental & regulatory constraints, exchange rates etc.)***

---

# GLOBAL SENSITIVITY ANALYSIS

- Wagner (1995)
- Summarizes complicated model in order to predict outcome via a few key IVs.
- Running the deterministic model multiple times for a variety of the IVs to produce a wide range of output.

- IVs

EOS

COM

TRANS1

TRANS2

- DVs

Market focus

Plant focus

Network Dispersion

# THE STRUCTURAL EQUATIONS

- Determines the most influential independent variables, using the estimate of one-at-a-time approach.
- Each dependent variable was regressed separately against a polynomial fit that allows various combinations of terms of the form  $x^a y^b z^c$
- Stepwise regression → best fit

$$\begin{aligned} \text{MARKET} = & -0.089 + 0.033 \text{ TRANS1}^{-1} - 0.018 \text{ TRANS1}^{-2} \cdot \text{TRANS2} - \\ & 0.0000536 \text{ TRANS1}^{-3} \cdot \text{TRANS2} + 0.0000000768 \text{ TRANS1}^{-1} \cdot \text{TRANS2}^{-2} - \\ & 0.0000000000373 \text{ TRANS1}^{-1} \cdot \text{TRANS2}^{-3} \end{aligned}$$

$$\begin{aligned} \text{PLANT} = & -12.537 + 9.875 \text{ COM}^{-1} + 0.003 \text{ EOS}^{-1} \cdot \text{COM}^{-2} + 0.428 \text{ COM}^{-1} + 3.752 \text{ COM} - \\ & 0.005 \text{ COM}^4 - 1.055 \text{ COM}^{-3} - 0.004 \text{ EOS}^{-1} \cdot \text{COM}^{-3} + 8.036 \text{ EOS} \cdot \text{COM}^3 - 5.751 \text{ EOS} \cdot \text{COM}^{-1} \end{aligned}$$

$$\begin{aligned} \text{DIS} = & -0.138 + 10.17 \text{ COM} \cdot \text{TRANS2} + 0.002 \text{ EOS}^{-1} \cdot \text{TRANS2} - 7.819 \text{ COM}^3 \cdot \text{TRANS2} - \\ & 2106.061 \text{ EOS}^3 \cdot \text{TRANS2} + 1.798 \text{ COM}^3 \cdot \text{TRANS2} - 1165.671 \text{ TRANS2}^4 \end{aligned}$$

# CONCLUSIONS FROM STRUCTURAL EQUATIONS MODELING OF INTERNATIONAL FACILITIES NETWORKS

## Main Contributions

1. ***A conceptual framework classifying global facility network structures along 3 dimensions that can be operationalized as a managerial tool to develop & monitor networks***
2. ***An approach for developing structural equations to classify network structures via relatively simple calculations of primary levers***
3. A decision tree and a robust set of equations under which firms can classify themselves into one of eight general “industry groups” without the need to run regressions
4. Illustration of the effects of subsidized financing & taxation on the strategic network structure as well as the tactical allocation of production among countries

## Impacts

1. ***Economies of scale, complexity costs, transportation costs, and tariffs affect the strategic network structure***
2. Given a network classification subsidized financing and taxations can significantly affect location decisions within the network

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# WHELAN PHARMACEUTICALS (HBS CASE)

- Location choice:
  - MD
  - PR
  - IRELAND
  - CONT. EUROPE
- Why do international tax planning?
  - Lots of \$ - Willie Sutton, Why Rob Banks?
  - Name companies with  $\geq 50\%$  of Revenues Int'l: (McDonald's, GM, Ford, ... )
  - Affects Supply Chain Location Decisions
- Discussion issues:
  - Basics of international taxation
  - How taxes affect supply chain decisions
  - How tax and nontax factors interact
  - Difficulty & importance of decisions

# PRESENTATION OUTLINE

- **Integrated Risk Management In Global Supply Chains**
  - Research
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    - Dynamic Production / Sourcing Strategies & Exchange Rate Uncertainty (“Hysteresis” phenomena)
    - Integrated Operational & Financial Hedging
  - Teaching
    - Examples
    - Cases: Applichem
- **Design & Planning of Global Supply Chain Network**
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    - Structural Equations Modeling (Global Sensitivity Analysis / Insights)
- **Global (Out)Sourcing Strategies**
  - Research
    - Stylized Modeling for Offshoring
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    - Case: Mattel (toy industry)
- **Future Research Directions**

# TO OFFSHORE OR NOT TO OFFSHORE

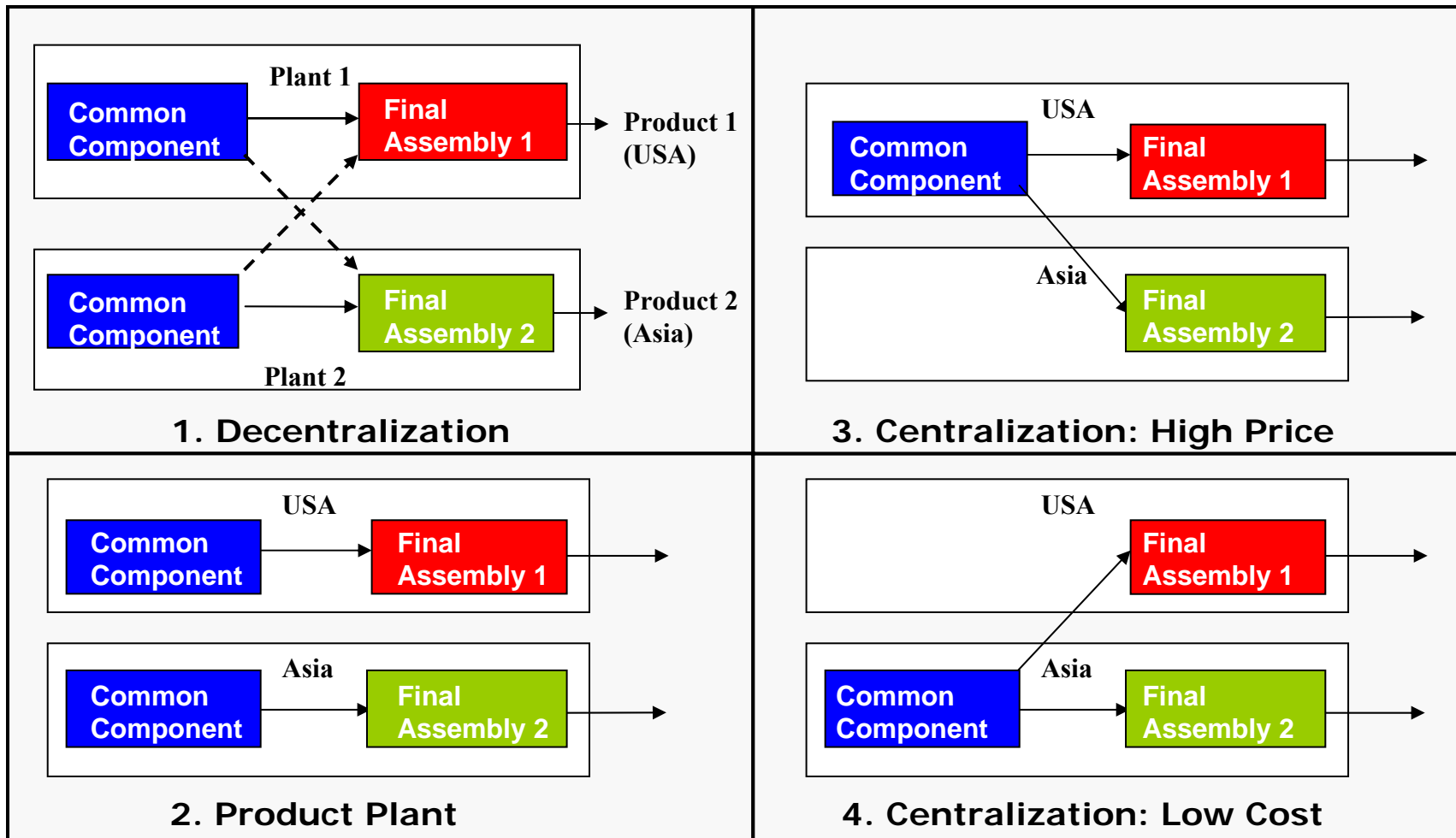
*A firm that manufactures two products to serve two geographically separated markets using a common component and two other product-specific components. The common part can be transported between the two markets that have different demand and financial characteristics.*

*Two strategic network design questions* arise naturally in this context:

(1) Should the common part be produced centrally or in two local facilities?

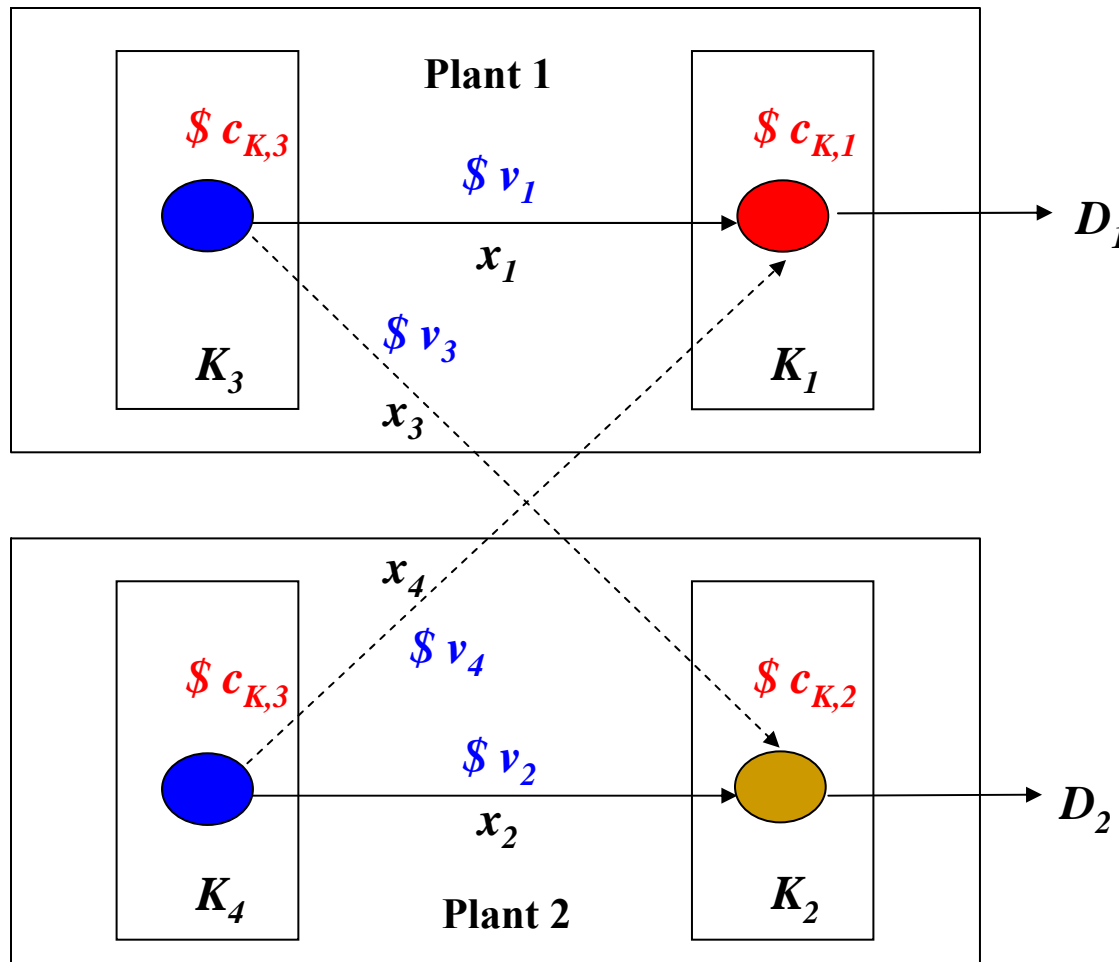
(2) If a centralization strategy is adopted for the common component, which market should the facility be located in?

# FOUR POSSIBLE CONFIGURATIONS OF A MULTIPLANT NETWORK



Reference: L. X. Lu and J. A. Van Miegham. 2006 "To Offshore or Not to Offshore: Sourcing and Location of Commonality in Multiplant Networks", Working paper, Kellogg, Northwestern Univ

# MODEL FORMULATION: NEWSVENDOR NETWORK PROBLEM



## Financial Characteristics:

- $c_K$  - Capacity Cost
- $c_M$  - Comm. Comp. Mfg. Cost
- $c_T$  - Transportation Cost
- $p$  - Price
- $v$  - Net Value

## Key Assumptions:

- Single period
- Investment decision made before demand is realized
- Linear production and financial structure
- $p_1 \geq p_2$        $\Delta p = p_1 - p_2$
- $c_{M,1} \geq c_{M,2}$        $\Delta c_M = c_{M,1} - c_{M,2}$

**Reference:** L. X. Lu and J. A. Van Mieghem. 2006 "To Offshore or Not to Offshore: Sourcing and Location of Commonality in Multiplant Networks", Working paper, Kellogg, Northwestern Univ

# OPTIMAL NETWORK CONFIGURATIONS: CENTRALIZE OR DECENTRALIZE? – HIGH & MEDIUM $\Delta P$

$$\bar{c}_T = \frac{\bar{P}_3 \Delta p - \Delta c_M - c_{K,1}}{1 - \bar{P}_3}$$

where  $\bar{P}_3 = P(D_1 > \bar{K}_1, D_2 > 0)$  and  $(\bar{K}_1, \bar{K}_2, \bar{K}_1, 0)$  is a boundary solution .

When  $\min(\Delta p, c_T) \geq \Delta c_M$ , the optimal investment strategy depends on the relative cost of transportation  $c_T$ :

- (i) If  $c_T < \bar{c}_T$ , it is optimal to centralize commonality in the high - price market.
- (ii) If  $c_T \geq \bar{c}_T$ , it is optimal to invest commonality in both markets.

**Reference:** L. X. Lu and J. A. Van Mieghem. 2006 "To Offshore or Not to Offshore: Sourcing and Location of Commonality in Multiplant Networks", Working paper, Kellogg, Northwestern Univ

# OPTIMAL NETWORK CONFIGURATIONS: CENTRALIZE OR DECENTRALIZE? – LOW $\Delta P$

$$\hat{c}_T = \frac{\Delta c_M - \hat{P}_3 \Delta p - c_{K,2}}{1 - \hat{P}_3}$$

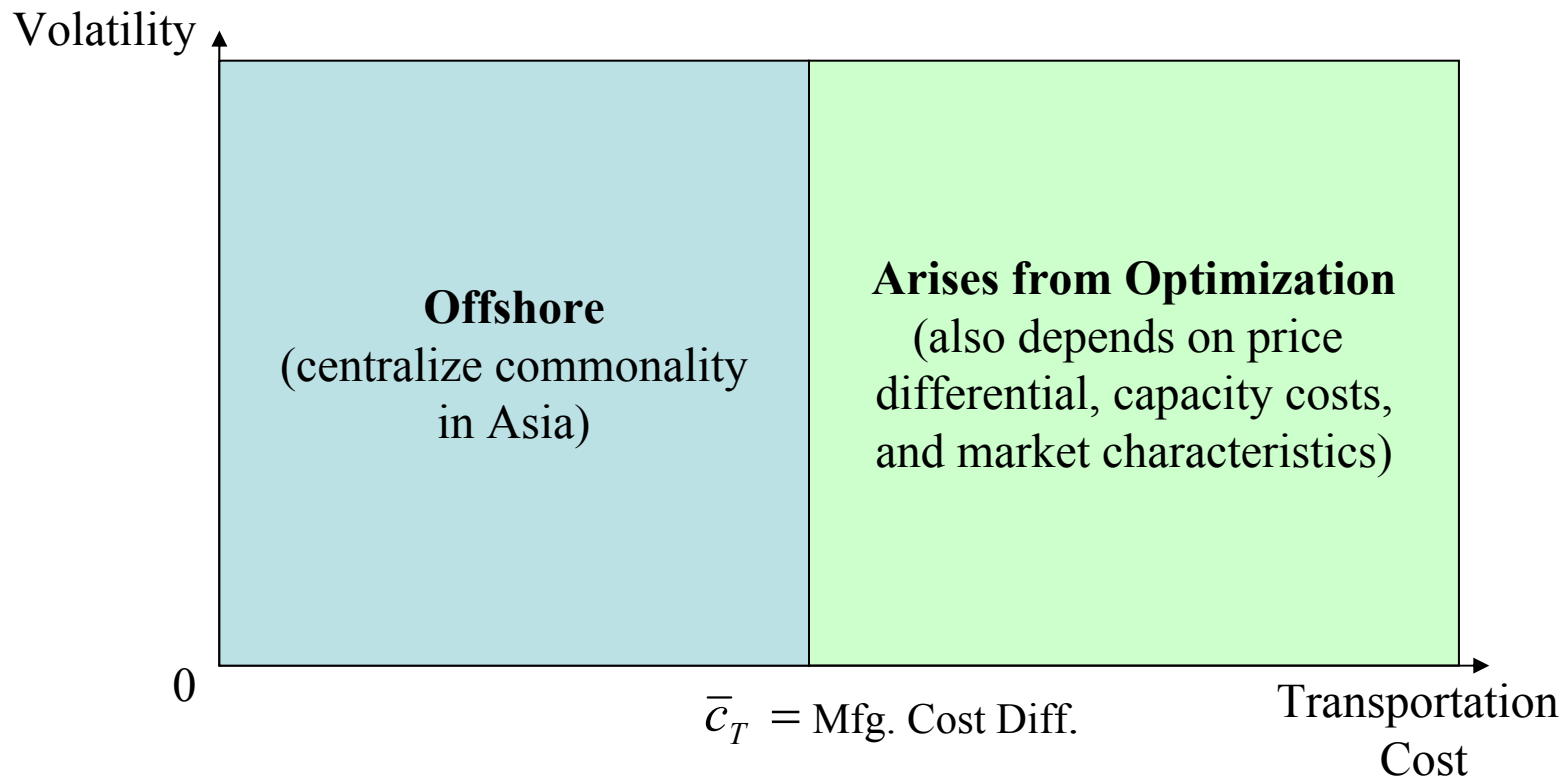
where  $\hat{P}_3 = P(D_1 > 0, D_2 > \hat{K}_2)$  and  $(\hat{K}_1, \hat{K}_2, 0, \hat{K}_2)$  is a boundary solution.

When  $\Delta c_M \geq \Delta p$ , the optimal investment strategy depends on the relative cost of transportation  $c_T$ :

- (i) If  $c_T < \hat{c}_T$ , it is optimal to centralize commonality in the low - cost market.
- (ii) If  $c_T \geq \hat{c}_T$ , it is optimal to invest commonality in both markets.

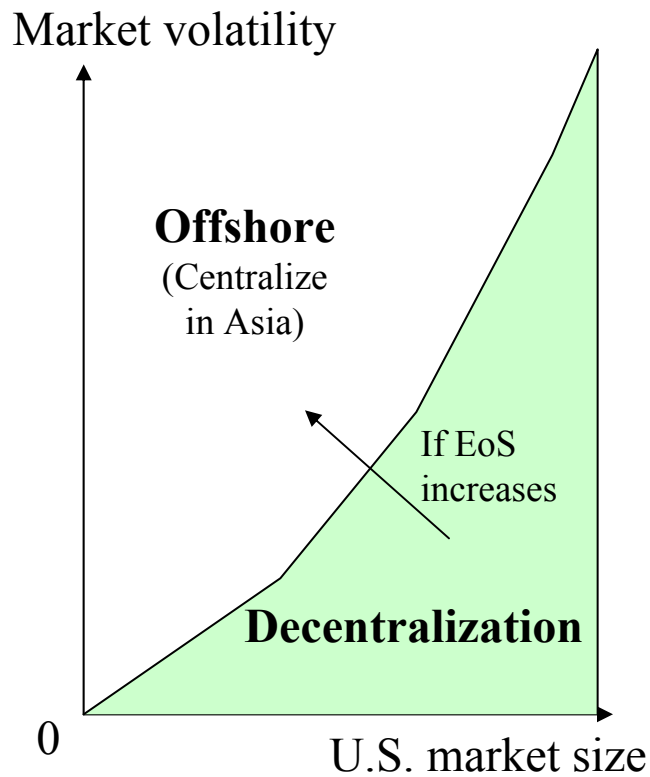
**Reference:** L. X. Lu and J. A. Van Mieghem. 2006 "To Offshore or Not to Offshore: Sourcing and Location of Commonality in Multiplant Networks", Working paper, Kellogg, Northwestern Univ

# MANAGERIAL INSIGHTS ON OFFSHORING



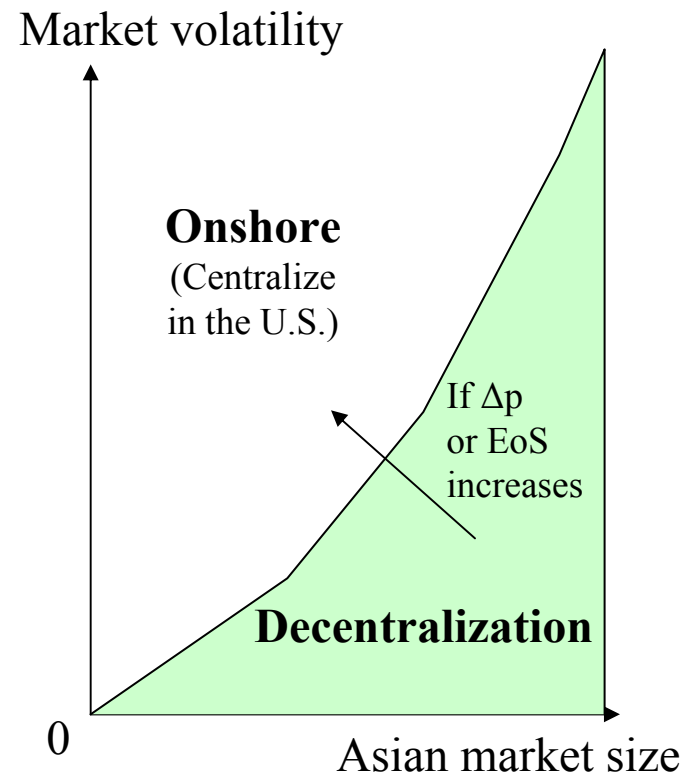
**Reference:** L. X. Lu and J. A. Van Mieghem. 2006 "To Offshore or Not to Offshore: Sourcing and Location of Commonality in Multiplant Networks", Working paper, Kellogg, Northwestern Univ

# MAKING OFFSHORING DECISIONS WHEN TRANSPORTATION IS EXPENSIVE



Low  $\Delta p$

$\Delta p$   
increases  
→

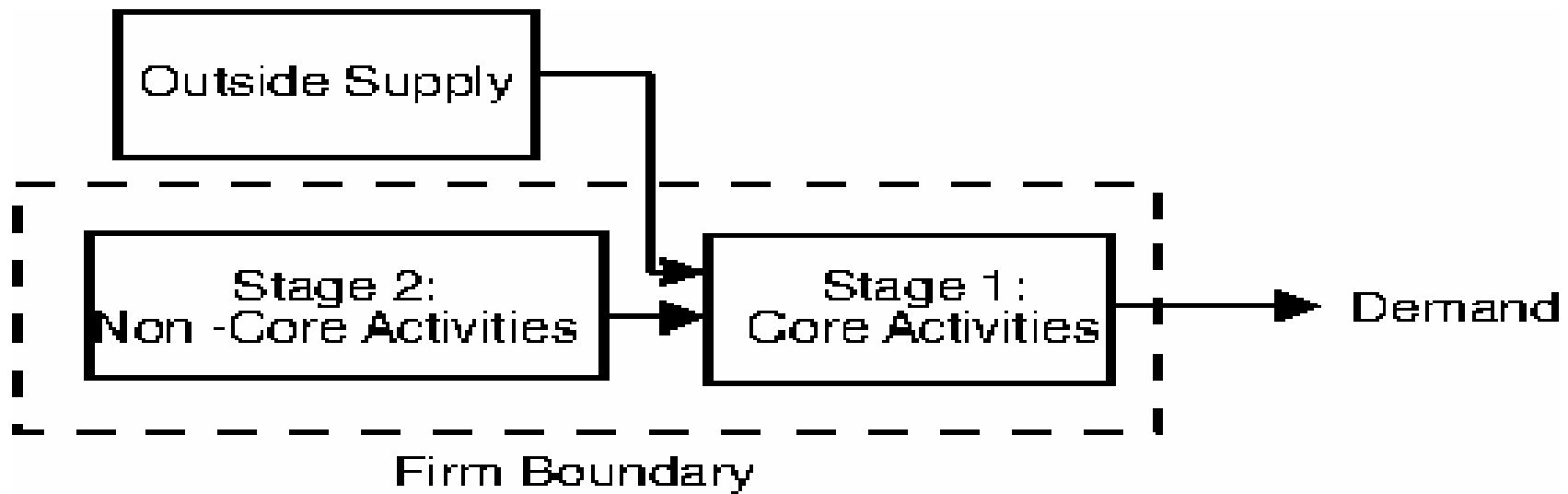


Medium to High  $\Delta p$

**Reference:** L. X. Lu and J. A. Van Mieghem. 2006 "To Offshore or Not to Offshore: Sourcing and Location of Commonality in Multiplant Networks", Working paper, Kellogg, Northwestern Univ

# SUPPLY CHAIN CAPACITY EXPANSION AND VERTICAL INTEGRATION

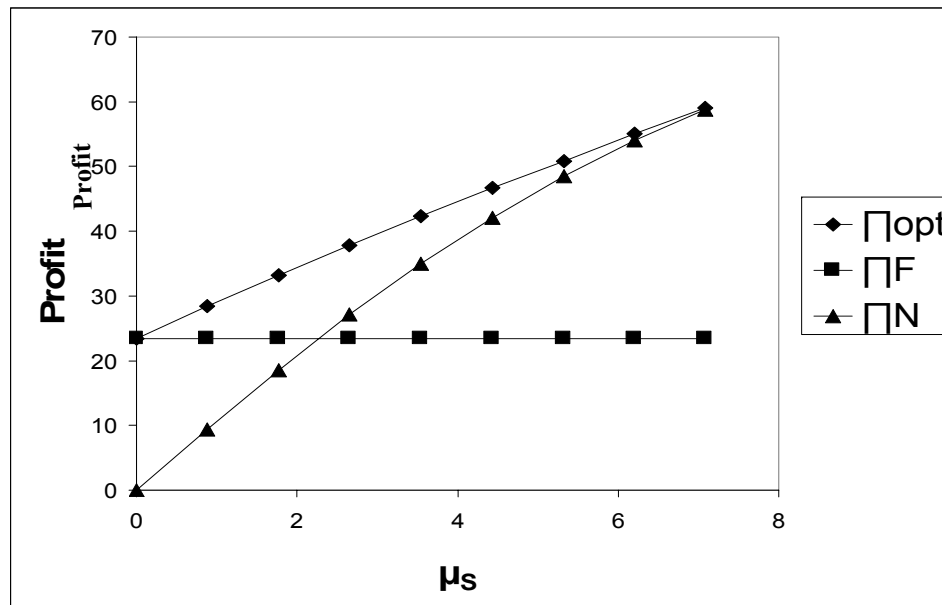
***What Are The Implications Of Supply And Demand Uncertainty For The Extent Of Vertical Integration Strategies Companies Use In Various Product Markets?***



- **CORE ACTIVITIES:** Firm exhibits strong competency, has effectively competed on, and demonstrates efficiency in executing (no outside supply of core activities)
- **NON-CORE ACTIVITIES:** Firm has not traditionally exhibited competency and/or invested substantially in the past (outside supply complements non-core output of the firm)

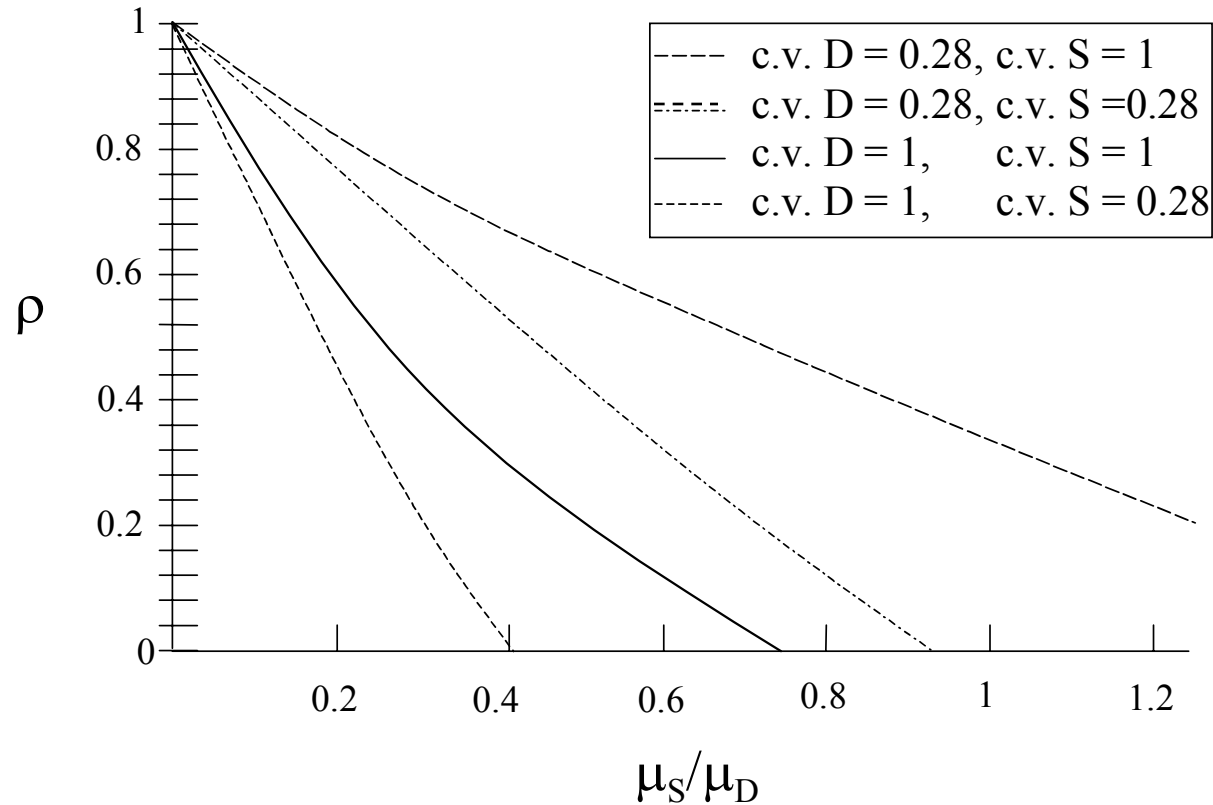
**Reference:** Kouvelis, P., Milner, J. M. "Supply Chain Capacity Expansion and Vertical Integration: The Dynamic interplay of Demand and Supply Uncertainty", IIE Trans, 34, 717-728

# EFFECTIVENESS OF EXTREME INTEGRATION POLICIES



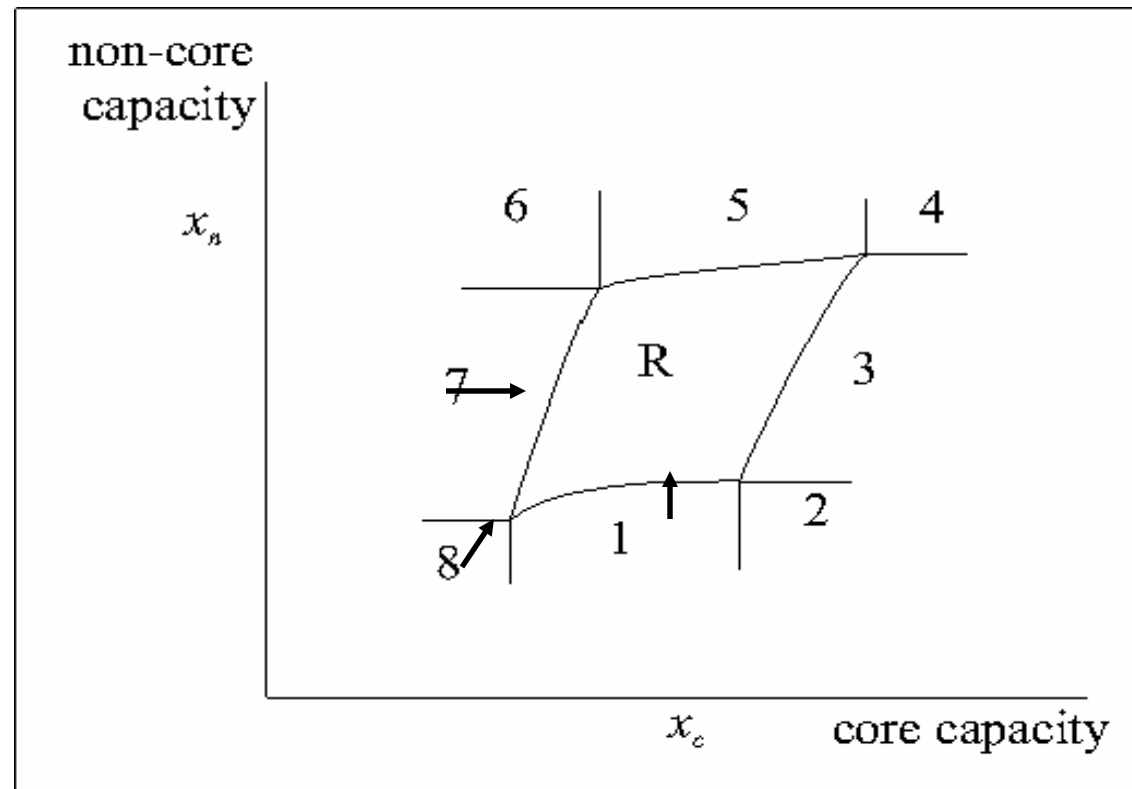
Profit performance of various policies at different levels of mean supply

## COMPUTATIONAL STUDY



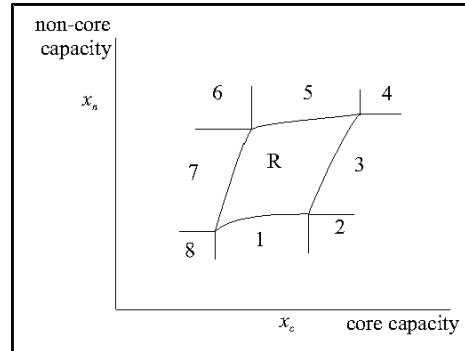
## Changes in Demand and Supply Distributions and Effects on Extent of Vertical Integration

# OPTIMALITY OF “INVESTMENT, STAY PUT, DISINVESTMENT (ISD)” POLICIES



The Borders of Region R are Upward Sloping( Supermodularity)

# DYNAMIC EFFECTS OF DEMAND AND SUPPLY CHANGES



Case	Possible Alternatives	Comment
Increasing Mean Demand	R,1,7,8	Higher $c_n$ implies 7 Higher $c_c$ implies 1
Increasing Mean Supply	R,5,6,7	Higher $c_c$ implies 5 Lower $r_n$ implies 7
Decreasing Demand Variance Core Capacity < Mean Demand	R,1,7,8	Higher $c_n$ implies 7 Higher $c_c$ implies 1
Decreasing Demand Variance Core Capacity > Mean Demand	R,3,4,5	Lower $r_n$ implies 3 Lower $r_c$ implies 5
Decreasing Supply Variance	R,3,4,5	Lower $r_n$ implies 3 Lower $r_c$ implies 5

Alternatives for Investment Change based on Supply and Demand Changes

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# SUPPLY CHAIN CAPACITY EXPANSION IN ENVIRONMENTS OF DEMAND AND SUPPLY UNCERTAINTY

## *CONDITIONS FOR INCREASED DEGREE OF VERTICAL INTEGRATION*

- Stronger Product Demand
- Weak or Limited Supply Infrastructure
- Decreased Demand Uncertainty
- Increased Supply Uncertainty
- Increased Cost of Outside Supply  
(Reverse Conditions for More Outsourcing)

# EXTENT OF VERTICAL INTEGRATION IN EMERGING MARKETS

<u>Types of Variables</u>	<u>Conditions of Variables</u>	
	Low	High
<u>Country Environment</u>		
Market Size and Growth	N-VI	F-VI
Labor Cost	N-VI	F-VI
Labor Skill	F-VI	N-VI
FG Import Control	N-VI	F-VI
RM Import Control	N-VI	F-VI
<u>Company Characteristics</u>		
• Product		
- Maturity	F-VI	N-VI
- Line Diversity	N-VI	F-VI
• Technology		
- Maturity	F-VI	N-VI
- Complexity	N-VI	F-VI
- Stability	F-VI	N-VI

# CASE: MATTEL – MANAGING GLOBAL OUTSOURCING & SUPPLY RISK IN THE TOY INDUSTRY

## Product Supply

### Manufacturing Capacity

- Outsourcing strategy
- Combine off-settings Seasonal Products

- Outsourcing improves economies of scale and asset utilizations
- Snow sleds and swimming pools

### Logistics Capacity

- Consolidation
- Supplemental Outsourcing
- Electronic Supply Chain
- Product Diversions
- Channel Coordination
- Retail Ready Products
- Air Freight

- Larger volumes create economies of scale
- Surge capacity during peaks outsourced
- Knowledge of channel inventory ensures product is supplied to those with true need
- Moving excess products to alternative or overseas channel
- Pre-distributed products reduce time to shelf
- Expensive air freight used only for late replenishments

### Currency Fluctuations

- Financial Hedging
- Diversify Supply
- Operational Hedging

- Contracts in stable currency, forward contracts
- Several supplier in different countries
- Several plants in different countries

### Supply Disruptions from Political issues

- Diversify Supply

- Several suppliers/plants in different countries

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## ■ Future Research Directions

---

# FUTURE RESEARCH DIRECTIONS

- Improved understanding of operational – financial hedging for global supply chains
  - Relative importance of various hedges
  - Operations/financial hedges: Complements or Substitutes
  - Other forms of operational hedges firms use in global SCs (acquisitions/product line/technology choices/channel strategies)
  - Operational hedges enhance value of firms: empirical evidence
  - Modeling of competitive exposure to exchange rates & rate of operational hedges

---

# FUTURE RESEARCH DIRECTIONS (CONTD.)

- Design & planning of global supply chains: refined understanding of planning ,location choice and SC design decision process; effect of non-traditional factors
  - Do taxes matter for location choices? For what firms? What aspects of International Taxation should enter our models?
  - Transfer pricing & global supply chain planning
  - Supply chain coordination & global environment: nature of coordinating contracts
  - Competition among global supply chains: implications for firms with limited control over supply chain
  - Survey of effects of regional trade agreements on global supply chains
  - Hierarchical planning process reflecting global organizational structure

---

# FUTURE RESEARCH DIRECTIONS (CONTD.)

- Global (out) sourcing strategies:
  - Selecting business process partners vs. suppliers
  - Partnership dynamics (from partnership to competition)
  - Refined understanding of risks & their management: operational (ability to execute in short term) vs. structural (relationship)
  - Outsourcing choices: not only location but also governance structure (spectrum of choices)
  - E-procurement & effects on global outsourcing
  - Role of intermediaries (supply chain integrators)