Supply Chain Outsourcing Under Exchange Rate Risk and Competition

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Outline

- Introduction
- Literature review
- Supply chain network with outsourcing under exchange rate risk and competition
- Simulation studies
- Conclusions.

Offshore Outsourcing

- Outsourcing manufacturing to lower-wage countries generally reduces production costs.
- From 2000 to 2007, 70 percent of U.S. non-oil import growth was driven by imports from developing countries with imports from China alone accounting for 39 percent of the growth.
- Offshore-outsourcing also exposes supply chain firms to various risks including: foreign exchange risk, production disruption risk, quality risk, supplier default risk, etc.

Foreign Exchange Risk

- Foreign exchange risk is consistently considered to be on the list of top concerns of supply chain executives.
- A study conducted by The Economist, which surveyed 500 global company executives with responsibility for risk management, showed that, in 2009, exchange rate uncertainty was ranked as the second most important risk factor next to demand uncertainty due to the economic recession. The executives ranked foreign exchange risk as their number one concern for the subsequent twelve months.
- In 2010 and 2011, the high volatility of the euro and possible appreciation of the Chinese yuan have posed significant risks to many companies involved in offshore outsourcing and global trades.

Literature Review

- The management of foreign exchange risk of supply chains has drawn considerable attention from researchers.
- Huchzermeier and Cohen (1996), Cohen and Huchzermeier (1999), Dasu and Li (1997), Kazaz et al. (2005), Goh et al. (2007).
- Nagurney et al. (2003), Nagurney and Matsypura (2005), Cruz et al. (2006).

Mean-variance Framework

- The mean-variance (MV) framework was originally introduced in the seminal work of the Nobel laureate Harry Markowitz.
- The MV approach has also been increasingly used in supply chain management studies to model the behaviors of decision-makers under risk and uncertainty.
- Lau (1980), Hodder (1984), Hodder and Jucker (1985), Lau and Lau (1999), Chen and Federgruen (2000), Gan et al. (2004, 2005). Choi et al. (2001, 2008a, 2008b), Wu (2009).

Supply Chain Outsourcing Under Exchange Rate Risk and Competition

We explicitly consider the firms' optimal pricing, production, and outsourcing decisions, and study how the firms with different risk attitudes behave when competition intensity and exchange rate uncertainty vary, and how such decisions affect their profits and risks.

We use simulation examples to answer the following: How do competition intensity and foreign exchange uncertainty affect:

- the offshore-outsourcing decisions of risk-neutral firms and those of risk-averse firms?
- the pricing strategies of risk-neutral firms and those of risk-averse firms?
- the profits of risk-neutral firms and those of risk-averse firms?
- the risks of risk-neutral firms and those of risk-averse firms?

Supply Chain Outsourcing Under Exchange Rate Risk and Competition (Con't)

- We consider M firms that sell partially substitutable products in the market of a developed country (e.g. the U.S. market).
- The manufacturers have choices of in-house production and/or outsourcing the manufacturing to suppliers in up to J countries.
- Producing the products in-house will require K raw materials and vendor-supplied parts.
- Each firm can decide the product price, the outsourced quantities, and the in-house production quantity.

Multi-Criteria Decision-Making Behavior of the Supply Chain Firms

Firm m's total cost at country j (in country j's currency), S_{mj}, can be expressed as:

$$S_{mj} = \sum_{k=1}^{K} c_{kj} u_{mkj} + h_{mj} v_{mj} + \sum_{k=1}^{K} t_{kj}^{1} u_{mkj} + t_{j}^{2} v_{mj}.$$

The expected total profit (in U.S. dollars) of firm m can, hence, be expressed as follows:

$$Profit_m = p_m d_m(P) - \sum_{k=1}^{K} \hat{c}_k \hat{u}_{mk} - \hat{h}_m \hat{q}_m - \sum_{j=1}^{J} \theta_j S_{mj}.$$

Multi-Criteria Decision-Making Behavior of the Supply Chain Firms

- Risk:
  The variance of the profit is equal to the variance of the total cost incurred in other countries, which can be expressed as: $r_m(U_m, V_m) = S_m^T COV_\theta S_m$, where COV_θ denotes the covariance matrix of exchange rates.

- Demand Function:

$$d_m(P) = a - p_m + \frac{1}{(M-1)} \sum_{n \neq m} \gamma \times (p_n - p_m)$$

  equivalently,

$$d_m(P) = a - (1+\gamma)p_m + \frac{\gamma}{(M-1)} \sum_{n \neq m} p_n$$

Multi-Criteria Decision-Making Behavior of the Supply Chain Firms

The optimization problem faced by firm m is:

$$MAX_{p_m, U_m, \hat{U}_m, V_m, \hat{q}_m} \; p_m d_m(P) - \sum_{k=1}^{K} \hat{c}_k \hat{u}_{mk} - \hat{h}_m \hat{q}_m - \sum_{j=1}^{J} \theta_j S_{mj} - \beta_m S_m^T COV_\theta S_m,$$

subject to:

$$\sum_{j=1}^{J} u_{mkj} + \hat{u}_{mk} = w_{mk} \hat{q}_m, \quad k = 1, \ldots, K; \tag{1}$$

$$\hat{q}_m \leq CAP_m; \tag{2}$$

$$d_m(P) = \hat{q}_m + \sum_{j=1}^{J} v_{mj}; \tag{3}$$

$$d_m(P) = a - (1+\gamma) p_m + \frac{\gamma}{(M-1)} \sum_{n \neq m} p_n, \tag{4}$$

$$p_m \geq 0, u_{mkj} \geq 0, \; \hat{u}_{mk} \geq 0, \; v_{mj} \geq 0, \; \hat{q}_m \geq 0, \quad j = 1, \ldots, J; \; k = 1, \ldots, K.$$

Theorem: Variational Inequality Formulation of the Supply Chain Equilibrium Under Exchange Rate Risk and Competition

The equilibrium conditions governing the supply chain under exchange rate risk and competition coincide with the solution of the variational inequality given by: determine $(P^*, U^*, \hat{U}^*, V^*, Q^*) \in \mathcal{K}^1$ *satisfying*

$$\sum_{m=1}^{M} \left[2(1+\gamma)p_m^* - a - \frac{\gamma}{(M-1)} \sum_{n \neq m} p_n^* \right] \times [p_m - p_m^*]$$

$$+ \sum_{m=1}^{M} \sum_{k=1}^{K} \sum_{j=1}^{J} \left[\theta_j c_{kj} + \theta_j t_{kj}^1 + \beta_m \frac{\partial r_m(U^*, V^*)}{\partial u_{mkj}} \right] \times [u_{mkj} - u_{mkj}^*]$$

$$+ \sum_{m=1}^{M} \sum_{k=1}^{K} \hat{c}_k \times [\hat{u}_{mk} - \hat{u}_{mk}^*] + \sum_{m=1}^{M} \sum_{j=1}^{J} \left[\theta_j h_{mj} + \theta_j t_j^2 + \beta_m \frac{\partial r_m(U^*, V^*)}{\partial v_{mj}} \right] \times [v_{mj} - v_{mj}^*]$$

$$+ \sum_{m=1}^{M} \hat{h}_m \times [\hat{q}_m - \hat{q}_m^*] \geq 0, \quad \forall (P, U, \hat{U}, V, Q) \in \mathcal{K}^1, \tag{5}$$

where $\mathcal{K}^1 \equiv \{(P, U, \hat{U}, V, Q) | (P, U, \hat{U}, V, Q) \in R_+^{M+MKJ+MK+MJ+M}$ *and* (1), (2), (3), *and* (4) *hold*$\}$.

Standard Form

The variational inequality problem (5) can be rewritten in standard form as follows: determine $X^* \in \mathcal{K}$ satisfying

$$\left\langle F(X^*)^T, X - X^* \right\rangle \geq 0, \quad \forall X \in \mathcal{K}, \tag{6}$$

where $X \equiv (P, U, \hat{U}, V, Q)^T$, $\mathcal{K} \equiv \mathcal{K}^1$, and

$$F(X) \equiv (F_m^P, F_{mkj}^U, F_{mk}^{\hat{U}}, F_{mj}^V, F_m^Q),$$

with indices $m = 1, \ldots, M$; $k = 1, \ldots, K$; and $j = 1, \ldots, J$, and the functional terms preceding the multiplication signs in (5), respectively. Here $< \cdot, \cdot >$ denotes the inner product in Ω-dimensional Euclidian space where $\Omega = M + MKJ + MK + MJ + M$.

Qualitative Properties

Theorem: Existence

There exists a solution to variational inequality (5).

Theorem: Monotonicity

The vector $F(X)$ that enters the variational inequality (6) as expressed in (5) is monotone, that is,

$$\left\langle (F(X') - F(X''))^T, X' - X'' \right\rangle \geq 0, \quad \forall X', X'' \in \mathcal{K}, X' \neq X''.$$

Modified Projection Method

Step 0: Initialization
Set $X^0 \in \mathcal{K}$. Let $\mathcal{T} = 1$ and let α be a scalar such that $0 < \alpha \leq \frac{1}{\mathrm{L}}$, where L is the Lipschitz continuity constant.

Step 1: Computation
Compute $\bar{X}^{\mathcal{T}}$ by solving the variational inequality subproblem:

$$\langle \bar{X}^{\mathcal{T}} + \alpha F(X^{\mathcal{T}-1}) - X^{\mathcal{T}-1}, X - \bar{X}^{\mathcal{T}} \rangle \geq 0, \quad \forall X \in \mathcal{K}.$$

Step 2: Adaptation
Compute $X^{\mathcal{T}}$ by solving the variational inequality subproblem:

$$\langle X^{\mathcal{T}} + \alpha F(\bar{X}^{\mathcal{T}}) - X^{\mathcal{T}-1}, X - X^{\mathcal{T}} \rangle \geq 0, \quad \forall X \in \mathcal{K}.$$

Step 3: Convergence Verification
If $\max |X_l^{\mathcal{T}} - X_l^{\mathcal{T}-1}| \leq \epsilon$, for all l, with $\epsilon > 0$, a prespecified tolerance, then stop; else, set $\mathcal{T} =: \mathcal{T} + 1$, and go to Step 1.

The method converges to a solution of the model provided that $F(X)$ is monotone and Lipschitz continuous, and a solution exists.

Empirical Case Study and Examples

We utilize a series of simulation examples to answer following questions: How do competition intensity and foreign exchange uncertainty affect:

- the offshore-outsourcing decisions of risk-neutral firms and those of risk-averse firms?
- the pricing strategies of risk-neutral firms and those of risk-averse firms?
- the profits of risk-neutral firms and those of risk-averse firms?
- the risks of risk-neutral firms and those of risk-averse firms?

Values of Simulation Parameters

- We consider two supply chain firms (M=2), one offshore-outsourcing country (J=1), and one raw material (K=1).
- We assume that one firm is risk-neutral ($\beta_1 = 0$) and the other firm is risk-averse ($\beta_2 = 0.25$).
- Based on the exchange rate volatilities in several normal and crisis periods, we assume that the exchange rate variance, σ^2, varies from 0 to 0.07 where σ^2 =0 and 0.005 represents low exchange variability; σ^2 =0.01 and 0.03 represents medium exchange rate uncertainty; and σ^2 =0.05 and 0.07 represents high foreign exchange risk.

Values of Simulation Parameters (Con't)

Notation	**Value**
Demand fuction	$d_m(P) = 20 - (1+\gamma)p_m + \gamma \sum_{n=1, n\neq m}^{2} p_n, \ \forall m.$
Material Cost in Country j	$c_{kj} = 8, \ \forall k, j$
Local Material Cost	$\hat{c}_k = 10, \ \forall k$
Purchasing Cost in Country j (including Country j's material cost, labor cost, and other costs)	$h_{mj} = 11.5, \ \forall m, j$
In-House Production Cost (including labor and other costs)	$\hat{h}_m = 5, \ \forall m$
Product Transportation Cost	$t^1_{kj} = 1, \ \forall k, j$
Material Transportation Cost	$t^2_j = 2, \ \forall j$
Material-Product Conversion Ratio	$w_{mk} = 1, \ \forall k, j$
Capacity	$CAP_m = 50, \ \forall m$
Expected Exchange Rate	$\theta_j = 1, \ \forall j$
Risk-Aversion Parameter	$\beta_1 = 0, \ \beta_2 = 0.25$
Competition Intensity	γ varies from 0 to 2 with the interval 0.4

Values of Simulation Parameters (Con't)

- We set the values of various cost parameters based on the recent PRTM global supply chain trends study which surveyed three hundred international firms, and reported relative savings in total costs, labor costs, material costs, and other costs due to offshore-outsourcing.
- Our cost and demand function parameters lead to 12% to 35% price-cost markups across different parameter combinations in the simulation results, which is consistent with the average markups of the manufacturing industries in various countries.

Two Strategies

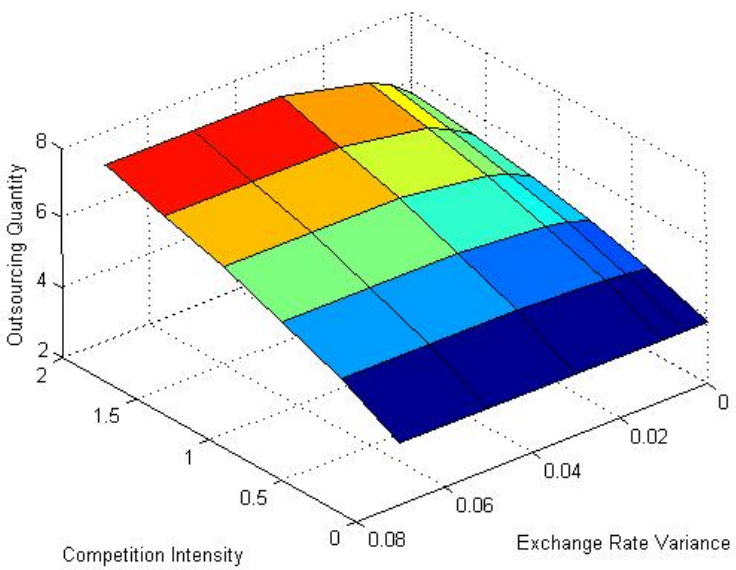
Firm 2, which is risk-averse, has two strategies to mitigate the impact of increasing exchange rate volatility:

- Strategy 1: To reduce outsourcing quantity and to increase the price of the product where the incremental price is used to compensate the foreign exchange risk;
- Strategy 2: To use more in-house production and to reduce the outsourcing quantity to lower the foreign exchange risk.

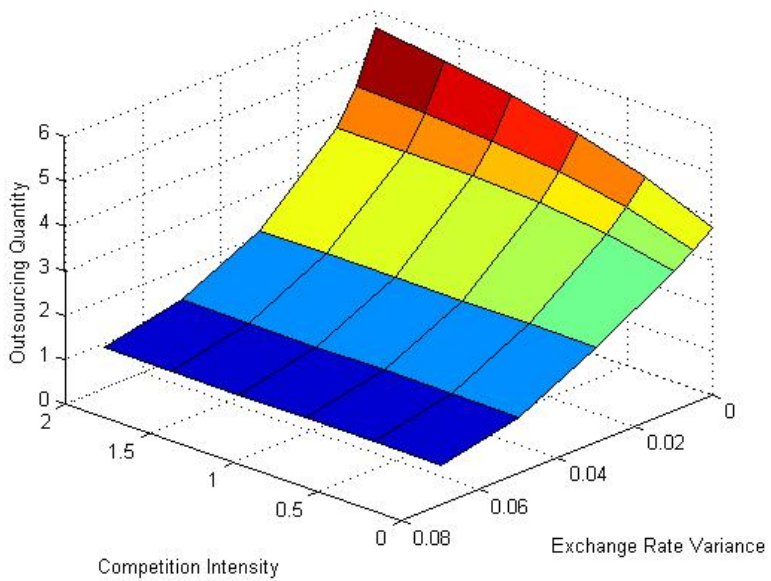
We find that Firm 2 mainly uses the first strategy when exchange rate uncertainty is low and mainly relies on the second strategy when the foreign exchange uncertainty is high.

Outsourcing Decisions of the Two Firms

Risk-neutral Firm



Risk-averse Firm



Outsourcing and In-House Production Decisions

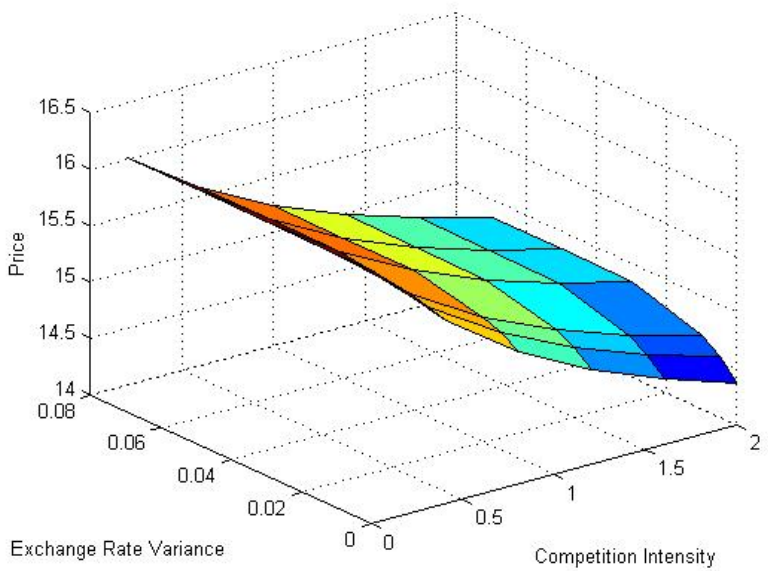
Panel 1: Risk-Neutral Firm		Competition Intensity					
Exchange Rate Variance		0.00	0.40	0.80	1.20	1.60	2.00
0.000	Outsourced	3.750	4.375	4.821	5.156	5.417	5.625
	In-House	0.000	0.000	0.000	0.000	0.000	0.000
	Total	3.750	4.375	4.821	5.156	5.417	5.625
0.005	Outsourced	3.750	4.452	4.991	5.429	5.798	6.117
	In-House	0.000	0.000	0.000	0.000	0.000	0.000
	Total	3.750	4.452	4.991	5.429	5.798	6.117
0.010	Outsourced	3.750	4.513	5.119	5.624	6.059	6.442
	In-House	0.000	0.000	0.000	0.000	0.000	0.000
	Total	3.750	4.513	5.119	5.624	6.059	6.442
0.030	Outsourced	3.750	4.630	5.347	5.967	6.521	7.031
	In-House	0.000	0.000	0.000	0.000	0.000	0.000
	Total	3.750	4.630	5.347	5.967	6.521	7.031
0.050	Outsourced	3.750	4.630	5.347	5.967	6.521	7.031
	In-House	0.000	0.000	0.000	0.000	0.000	0.000
	Total	3.750	4.630	5.347	5.967	6.521	7.031
0.070	Outsourced	3.750	4.630	5.347	5.967	6.521	7.031
	In-House	0.000	0.000	0.000	0.000	0.000	0.000
	Total	3.750	4.630	5.347	5.967	6.521	7.031
Panel 2: Risk-Averse Firm		Competition Intensity					
Exchange Rate Variance		0.00	0.40	0.80	1.20	1.60	2.00
0.000	Outsourced	3.750	4.375	4.821	5.156	5.417	5.625
	In-House	0.000	0.000	0.000	0.000	0.000	0.000
	Total	3.750	4.375	4.821	5.156	5.417	5.625
0.005	Outsourced	3.416	3.859	4.133	4.306	4.413	4.477
	In-House	0.000	0.000	0.000	0.000	0.000	0.000
	Total	3.416	3.859	4.133	4.306	4.413	4.477
0.010	Outsourced	3.137	3.451	3.616	3.696	3.724	3.719
	In-House	0.000	0.000	0.000	0.000	0.000	0.000
	Total	3.137	3.451	3.616	3.696	3.724	3.719
0.030	Outsourced	2.133	2.133	2.133	2.133	2.133	2.133
	In-House	0.367	0.528	0.555	0.494	0.373	0.210
	Total	2.500	2.662	2.688	2.627	2.507	2.344
0.050	Outsourced	1.280	1.280	1.280	1.280	1.280	1.280
	In-House	1.220	1.381	1.408	1.347	1.227	1.064
	Total	2.500	2.662	2.688	2.627	2.507	2.344
0.070	Outsourced	0.914	0.914	0.914	0.914	0.914	0.914
	In-House	1.586	1.747	1.774	1.713	1.592	1.429
	Total	2.500	2.662	2.688	2.627	2.507	2.344

Outsourcing and In-House Production Decisions (Con't)

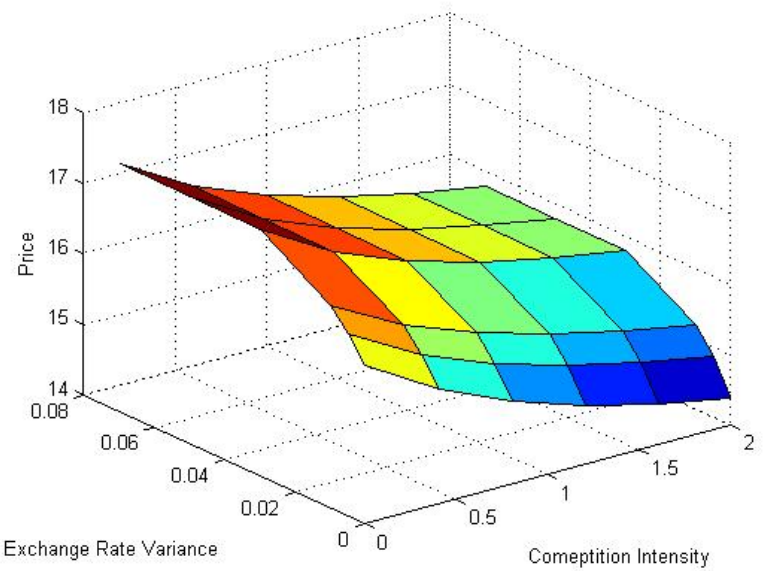
- The results in the table answers the second question raised in the Introduction.
- When the exchange rate variability increases, the outsourcing activities of the risk-averse firm always decrease while the outsourcing activities of the risk-neutral firm are always nondecreasing, and will increase when the exchange risk is low to medium.
- Since risk-aversion is the prevalent decision-making behavior in business and economics we expect that in most cases increasing exchange rate variability should reduce overall offshore-outsourcing activities.
- For example, various empirical studies found that rising exchange rate variability significantly reduces imports in U.S., U.K., and European Union.
- However, our results also indicate that in certain circumstances or periods if there are more decision-makers who are relatively risk insensitive, the offshore-outsourcing activities may not be greatly affected by the increase of exchange rate uncertainty. Indeed, some empirical studies reported weak impacts of exchange rate volatility on imports to developed countries.

Product Prices of the Two Firms

Risk-neutral Firm



Risk-averse Firm



Pricing Strategy, Average Costs, and Markups

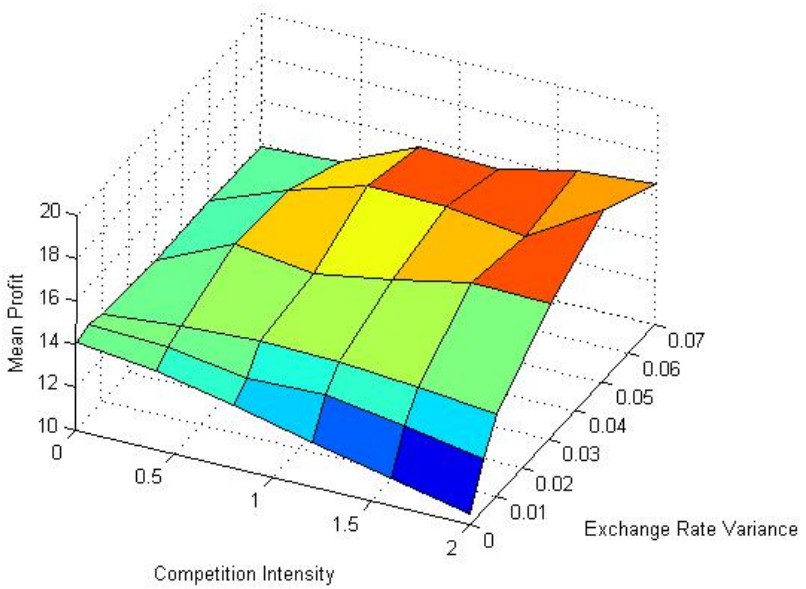
Panel 1: Risk-Neutral Firm		Competition Intensity					
Exchange Rate Variance		0.00	0.40	0.80	1.20	1.60	2.00
0.000	Price	16.250	15.625	15.179	14.844	14.583	14.375
	Avg Cost	12.500	12.500	12.500	12.500	12.500	12.500
	Markup	30.00%	25.00%	21.43%	18.75%	16.67%	15.00%
0.005	Price	16.250	15.680	15.273	14.968	14.730	14.539
	Avg Cost	12.451	12.508	12.560	12.453	12.477	12.513
	Markup	30.51%	25.36%	21.60%	20.19%	18.05%	16.19%
0.010	Price	16.250	15.723	15.344	15.057	14.831	14.647
	Avg Cost	12.500	12.531	12.495	12.473	12.486	12.498
	Markup	30.00%	25.48%	22.80%	20.72%	18.77%	17.20%
0.030	Price	16.250	15.807	15.471	15.212	15.008	14.844
	Avg Cost	12.547	12.447	12.660	12.590	12.495	12.526
	Markup	29.52%	26.99%	22.20%	20.83%	20.12%	18.50%
0.050	Price	16.250	15.807	15.471	15.212	15.008	14.844
	Avg Cost	12.508	12.486	12.386	12.465	12.572	12.281
	Markup	29.92%	26.60%	24.91%	22.04%	19.38%	20.87%
0.070	Price	16.250	15.807	15.471	15.212	15.008	14.844
	Avg Cost	12.555	12.772	12.554	12.622	12.509	12.491
	Markup	29.43%	23.76%	23.23%	20.52%	19.97%	18.84%
Panel 2: Risk-Averse Firm		Competition Intensity					
Exchange Rate Variance		0.00	0.40	0.80	1.20	1.60	2.00
0.000	Price	16.250	15.625	15.179	14.844	14.583	14.375
	Avg Cost	12.500	12.500	12.500	12.500	12.500	12.500
	Markup	30.00%	25.00%	21.43%	18.75%	16.67%	15.00%
0.005	Price	16.584	16.010	15.603	15.298	15.059	14.867
	Avg Cost	12.452	12.508	12.560	12.453	12.477	12.513
	Markup	33.18%	28.00%	24.23%	22.85%	20.69%	18.81%
0.010	Price	16.863	16.313	15.922	15.624	15.387	15.192
	Avg Cost	12.500	12.531	12.495	12.473	12.486	12.498
	Markup	34.90%	30.19%	27.43%	25.26%	23.23%	21.56%
0.030	Price	17.500	16.901	16.494	16.194	15.964	15.781
	Avg Cost	12.906	12.954	13.143	13.043	12.868	12.748
	Markup	35.59%	30.47%	25.50%	24.16%	24.06%	23.79%
0.050	Price	17.500	16.901	16.493	16.194	15.964	15.781
	Avg Cost	13.724	13.791	13.755	13.765	13.760	13.515
	Markup	27.52%	22.55%	19.91%	17.65%	16.02%	16.77%
0.070	Price	17.500	16.901	16.494	16.194	15.964	15.781
	Avg Cost	14.106	14.235	14.168	14.173	14.092	14.021
	Markup	24.06%	18.73%	16.41%	14.26%	13.29%	12.55%

Pricing Strategy, Average Costs, and Markups (Con't)

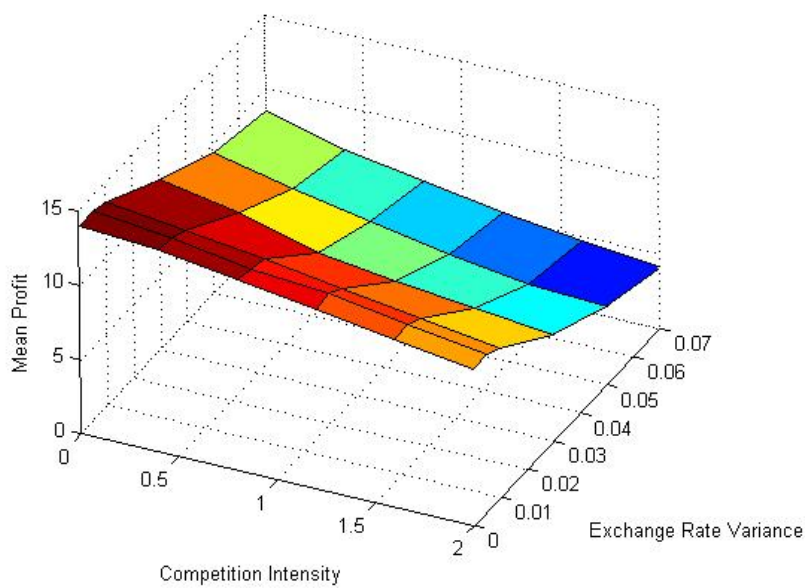
- The results in the table answers the second question raised in the Introduction.
- The markups of the two firms across different scenarios range from 12% to 35%, which is consistent with the reported average markups of the manufacturing industries in different countries
- For both risk-neutral and risk-averse firms the market prices and the markups consistently decrease as the competition intensity increases. This indicates that higher competition intensity leads to lower profit margins for both firms at all uncertainty levels.
- As the exchange rate uncertainty becomes higher the prices in general do not respond significantly.
- When the exchange rate variability is from low to medium the product prices slightly increase with the exchange uncertainty. Such marginal increase is due to the fact the risk-averse firm uses the first strategy to cope with the risk.

Profits of the Two Firms

Risk-neutral Firm



Risk-averse Firm



Profits of the Two Firms (Con't)

Panel 1: Risk-Neutral Firm		Competition Intensity						
Exchange Rate Variance		0.00	0.40	0.80	1.20	1.60	2.00	slope
0.000	Average	14.064	13.673	12.913	12.086	11.286	10.546	-1.83^{***}
	Lower Limit	14.064	13.673	12.913	12.086	11.286	10.546	
	Upper Limit	14.064	13.673	12.913	12.086	11.286	10.546	
0.005	Average	14.245	14.123	13.540	13.652	13.059	12.394	-0.88^{***}
	Lower Limit	14.030	13.876	13.264	13.361	12.736	12.062	
	Upper Limit	14.460	14.371	13.816	13.943	13.381	12.726	
0.010	Average	14.063	14.407	14.582	14.532	14.204	13.847	-0.12
	Lower Limit	13.765	14.056	14.196	14.104	13.737	13.345	
	Upper Limit	14.360	14.758	14.969	14.961	14.671	14.349	
0.030	Average	13.887	15.557	15.030	15.645	16.391	16.297	1.08^{*}
	Lower Limit	13.388	14.944	14.298	14.851	15.509	15.347	
	Upper Limit	14.386	16.169	15.762	16.440	17.274	17.247	
0.050	Average	14.032	15.377	16.497	16.389	15.888	18.020	1.53^{*}
	Lower Limit	13.380	14.589	15.546	15.355	14.745	16.826	
	Upper Limit	14.685	16.166	17.447	17.423	17.031	19.214	
0.070	Average	13.855	14.052	15.596	15.456	16.295	16.546	1.43^{**}
	Lower Limit	13.078	13.101	14.498	14.227	14.955	15.125	
	Upper Limit	14.632	15.003	16.693	16.684	17.634	17.966	
Panel 2: Risk-Averse Firm		Competition Intensity						
Exchange Rate Variance		0.00	0.40	0.80	1.20	1.60	2.00	slope
0.000	Average	14.064	13.673	12.913	12.086	11.286	10.546	-1.83^{***}
	Lower Limit	14.064	13.673	12.913	12.086	11.286	10.546	
	Upper Limit	14.064	13.673	12.913	12.086	11.286	10.546	
0.005	Average	14.116	13.512	12.576	12.25	11.395	10.54	-1.75^{***}
	Lower Limit	13.920	13.298	12.347	12.019	11.150	10.297	
	Upper Limit	14.312	13.727	12.804	12.481	11.641	10.783	
0.010	Average	13.686	13.054	12.392	11.646	10.799	10.018	-1.85^{***}
	Lower Limit	13.437	12.785	12.119	11.364	10.513	9.728	
	Upper Limit	13.935	13.322	12.665	11.927	11.086	10.308	
0.030	Average	11.484	10.504	9.007	8.278	7.760	7.109	-2.20^{***}
	Lower Limit	11.200	10.222	8.715	7.994	7.471	6.820	
	Upper Limit	11.768	10.787	9.300	8.562	8.048	7.397	
0.050	Average	9.440	8.276	7.362	6.382	5.524	5.312	-2.13^{***}
	Lower Limit	9.217	8.058	7.134	6.160	5.300	5.095	
	Upper Limit	9.662	8.494	7.589	6.603	5.749	5.530	
0.070	Average	8.485	7.096	6.251	5.311	4.692	4.124	-2.14^{***}
	Lower Limit	8.296	6.908	6.063	5.122	4.504	3.939	
	Upper Limit	8.675	7.283	6.438	5.499	4.880	4.309	
***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$		The upper and lower limits are based on 95% confidence interval						

Profits of the Two Firms (Con't)

- The results in the table answers the third question raised in the Introduction.
- When the exchange rate variability is non-zero, the risk-neutral firm has a significantly higher *average* profit than the risk-averse firm.
- The competition intensity always has a significantly negative impact on the risk-averse firm's average profit at all uncertainty levels.
- The signs and the significance of the slopes imply that the average profit of the risk-neutral firm is significantly negatively influenced by the competition intensity when the exchange rate variability is low while it is significantly positively affected by the competition when the exchange uncertainty is high.
- The risk-averse firm's profit always decreases as the exchange uncertainty rises.
- The profit of the risk-neutral firm will increase with the exchange rate variability when the uncertainty is less than 0.050, and will not change significantly when the uncertainty is greater than or equal to 0.050.

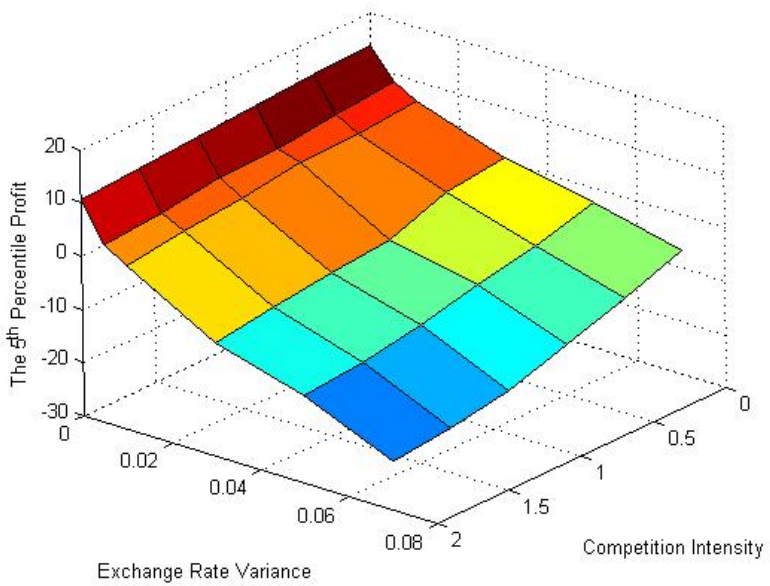
Probability that the Risk-Neutral Firm Has Higher Profit

		Competition Intensity					
Exchange Rate Variance		0.00	0.40	0.80	1.20	1.60	2.00
0.000	Point Estimate	N/A	N/A	N/A	N/A	N/A	N/A
	Lower Limit	N/A	N/A	N/A	N/A	N/A	N/A
	Upper Limit	N/A	N/A	N/A	N/A	N/A	N/A
0.005	Point Estimate	66.30%	86.90%	89.90%	93.40%	90.50%	89.20%
	Lower Limit	63.37%	84.81%	88.03%	91.86%	88.68%	87.27%
	Upper Limit	69.23%	88.99%	91.77%	94.94%	92.32%	91.13%
0.010	Point Estimate	70.60%	84.30%	89.00%	89.50%	87.00%	85.70%
	Lower Limit	67.77%	82.04%	87.06%	87.60%	84.91%	83.53%
	Upper Limit	73.43%	86.56%	90.94%	91.40%	89.09%	87.87%
0.030	Point Estimate	76.00%	82.60%	79.60%	81.20%	80.50%	81.40%
	Lower Limit	73.35%	80.25%	77.10%	78.78%	78.04%	78.99%
	Upper Limit	78.65%	84.95%	82.10%	83.63%	82.96%	83.82%
0.050	Point Estimate	75.20%	79.40%	76.60%	77.90%	75.10%	78.70%
	Lower Limit	72.52%	76.89%	73.97%	75.33%	72.42%	76.16%
	Upper Limit	77.88%	81.91%	79.23%	80.48%	77.78%	81.24%
0.070	Point Estimate	71.60%	70.40%	72.70%	72.80%	73.00%	72.80%
	Lower Limit	68.80%	67.57%	69.94%	70.04%	70.25%	70.04%
	Upper Limit	74.40%	73.23%	75.47%	75.56%	75.76%	75.56%
The upper and lower limits are based on 95% confidence interval							

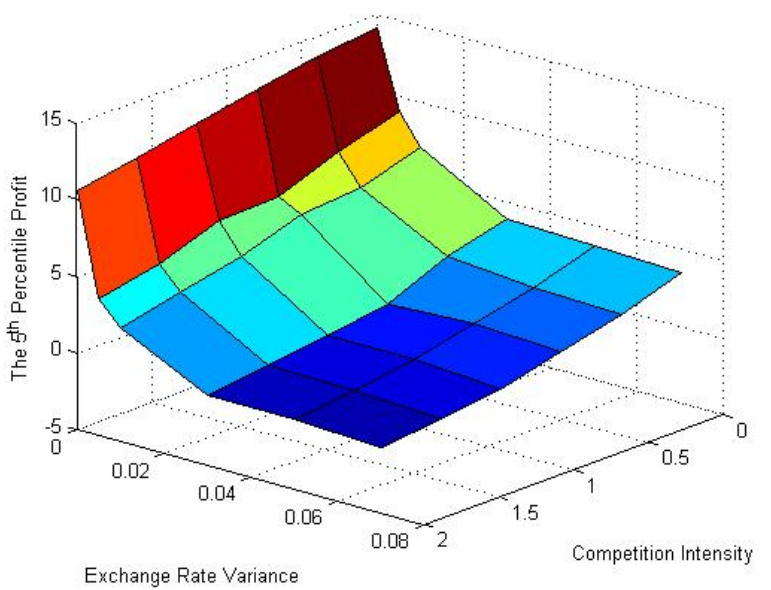
The risk-neutral firm has significantly higher probability to obtain more profit than the risk-averse firm across all combinations of exchange rate variability and competition intensity.

The 5^{th} Percentile Profits of the Two Firms

Risk-neutral Firm



Risk-averse Firm



Risks of the Two Firms

Panel 1: Risk-Neutral Firm		Competition Intensity						
Exchange Rate Variance		0.00	0.40	0.80	1.20	1.60	2.00	slope
0.005	CV	0.244	0.282	0.329	0.343	0.398	0.432	0.09^{***}
	5th Percentile	8.636	7.498	6.036	5.986	4.348	3.462	-2.53^{***}
	1st Percentile	5.443	4.131	3.086	1.941	0.857	0.069	-2.70^{***}
0.010	CV	0.341	0.393	0.427	0.475	0.530	0.584	0.12^{***}
	5th Percentile	6.156	4.963	4.934	3.211	2.110	0.732	-2.67^{***}
	1st Percentile	3.104	1.254	0.814	-1.587	-1.338	-3.862	-3.21^{**}
0.030	CV	0.580	0.634	0.785	0.818	0.867	0.939	0.18^{***}
	5th Percentile	0.564	-0.905	-4.514	-5.669	-7.098	-8.525	-4.66^{***}
	1st Percentile	-4.965	-6.104	-11.247	-13.621	-17.389	-19.570	-7.80^{***}
0.050	CV	0.749	0.826	0.928	1.017	1.159	1.068	0.19^{**}
	5th Percentile	-2.848	-5.651	-7.956	-10.458	-12.429	-13.369	-5.39^{***}
	1st Percentile	-11.168	-14.739	-16.645	-22.139	-28.160	-28.175	-9.34^{***}
0.070	CV	0.904	1.091	1.134	1.281	1.325	1.383	0.23^{***}
	5th Percentile	-6.554	-10.613	-14.162	-17.705	-19.537	-20.663	-7.20^{***}
	1st Percentile	-15.446	-20.051	-30.441	-28.872	-35.111	-36.108	-10.49^{**}
Panel 2: Risk-Averse Firm		Competition Intensity						
Exchange Rate Variance		0.00	0.40	0.80	1.20	1.60	2.00	slope
0.005	CV	0.224	0.256	0.293	0.303	0.347	0.372	0.07^{***}
	5th Percentile	9.006	7.770	6.362	6.170	4.764	4.002	-2.44^{***}
	1st Percentile	6.097	4.852	3.920	2.962	2.107	1.519	-2.29^{***}
0.010	CV	0.293	0.331	0.355	0.390	0.428	0.466	0.08^{***}
	5th Percentile	7.071	5.831	5.576	4.206	3.367	2.447	-2.28^{***}
	1st Percentile	4.518	2.995	2.665	1.053	1.249	-0.204	-2.18^{**}
0.030	CV	0.399	0.433	0.523	0.553	0.599	0.653	0.13^{***}
	5th Percentile	3.905	2.920	1.211	0.657	0.076	-0.422	-2.19^{**}
	1st Percentile	0.759	0.524	-1.475	-2.186	-3.291	-3.773	-2.49^{***}
0.050	CV	0.380	0.424	0.498	0.560	0.654	0.659	0.15^{***}
	5th Percentile	3.678	2.464	1.509	0.623	-0.033	-0.402	-2.06^{***}
	1st Percentile	0.838	-0.049	-0.571	-1.884	-3.121	-3.097	-2.16^{***}
0.070	CV	0.360	0.426	0.484	0.571	0.645	0.722	0.18^{***}
	5th Percentile	3.510	2.226	1.163	0.230	-0.331	-0.714	-2.12^{***}
	1st Percentile	1.342	0.362	-1.620	-1.482	-2.515	-2.722	-2.06^{**}
***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$								

Risks of the Two Firms (Con't)

- The results in the table answers the third question raised in the Introduction.
- The risk-averse firm consistently has lower risk than the risk-neutral firm across all scenarios.
- The signs and the significance of the slopes suggest that the exchange risks significantly increase with the competition intensity. The reason is that intense competition can lower the profit margins and/or force the firms to increase their offshore-outsourcing activities which result in higher exchange risk exposure.
- These results provide explanations to the recent empirical findings in Francis et al. (2008) where the study found that the industry competition intensity significantly increases American firms' exchange risks related to developing countries.

Risks of the Two Firms (Con't)

- For the risk-neutral firm, all risk measures become worse as the exchange rate variability increases while for the risk-averse firm when the exchange rate uncertainty goes up the three risk measures first get worse till the variance is equal to 0.030, and then become better or mixed when the variability gets higher.
- The reason is that after the exchange rate uncertainty is greater than 0.030 the risk-averse firm starts to use the second strategy to switch back to in-house production which reduces its exposure to the exchange uncertainty.

Managerial Insights

- If the firm is more concerned about risk.
  - they should try to differentiate their products from their competitors since intense competition will both reduce their profitability and increase their risk.
  - In addition, they should also maintain certain in-house production capacity for operational hedging purposes when the exchange rate uncertainty is high.
- For the firms that are not sensitive to risk high exchange rate.
  - Uncertainty may provide opportunity for them to get an edge on the competition with more risk-averse firms. For example, when the exchange rate variability is relatively high they should expand their outsourcing operations in order to gain more market share from more risk-sensitive competitors which may help them increase average profits.
  - However, the firms that exploit these opportunities should understand that such strategies can also cause significant risk and loss.

Conclusions

- This paper studied the impact of foreign exchange rate uncertainty and competition intensity on supply chain firms who are involved in offshore outsourcing activities.
- We developed a variational inequality model that considers firms' decision-making regarding pricing, material procurement, offshore-outsourcing, transportation, and in-house production under competition and foreign exchange rate uncertainty.
- Our model also allowed the firms to have different attitudes toward risk.
- We provided important qualitative properties for the model and presented an algorithm that was guaranteed to converge.
- We utilized a series of simulation examples to answer four interesting questions regarding supply chain firms' pricing and outsourcing decisions, and the associated profits and risks.

Thank You!