Product Variety, Complexity, and The Bottleneck of Coordination

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Motivation

Pursuing product variety and innovation is an important competition strategy (Adner and Levinthal 2001, Brander and Eaton 1984, Schmalensee 1978, Caves and Ghemawat 1992, Perloff and Salop 1982).

- Variety ➔more market share and less price competition ➔ revenue

Motivation

Pursuing product variety and innovation is an important competition strategy (Adner and Levinthal 2001, Brander and Eaton 1984, Schmalensee 1978, Caves and Ghemawat 1992, Perloff and Salop 1982).

- Variety ➔more market share and less price competition ➔ revenue

Yet, introducing a large number of product varieties often leads to firm failure

- Adaptation, disruption, and mortality (Barnett and Freeman 2001, Cottrell and Nault 2004, Sorensen 2000)
- Complexity and knowledge management (Dowell 2006, MacDuffie et al. 1996)

Research questions:

- *How does product variety affect **operational complexity**?*
- *How does **organizational structure** affect the efficiency of a product proliferation strategy?*

Summary of Findings

Empirical context

- The largest bottling company within a major soft drink company

Main findings:

- Product variety ➔ complexity in inter-unit sourcing relationships
- Complex sourcing relationships ➔ coordination challenges ➔ lower level of service (LOS)
- A hierarchical structure with sourcing hubs reduces complexity for the entire network but gives rise to coordination bottleneck at these hubs and worsens LOS for units sourcing through these hubs

Contributions:

- Product variety
  - Variety ➔ Coordination challenges ➔Lower performance
- Complexity
  - Source of interdependencies and challenges of structural design
  - Loci and bottlenecks of coordination in complex systems
- Stockouts (OM)
  - Coordination challenges *between* organizational units

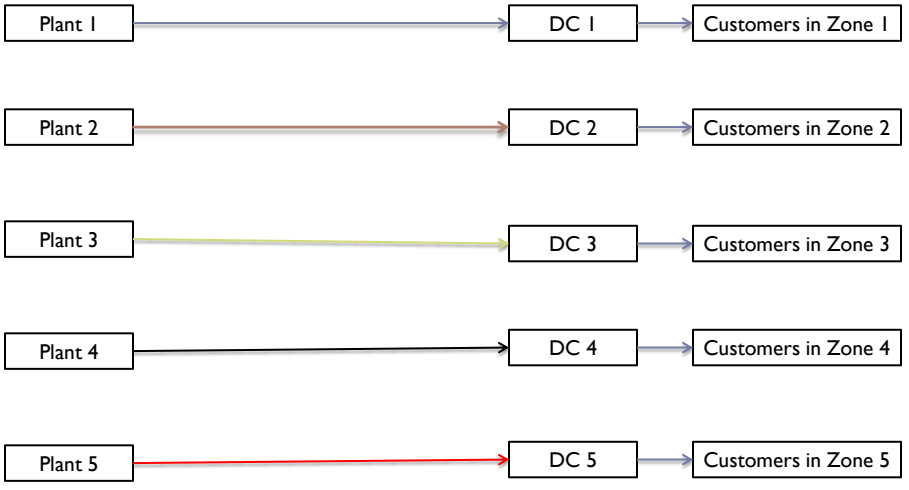
Product Variety and Sourcing Complexity

Scale and scope economies arising from fixed cost inputs

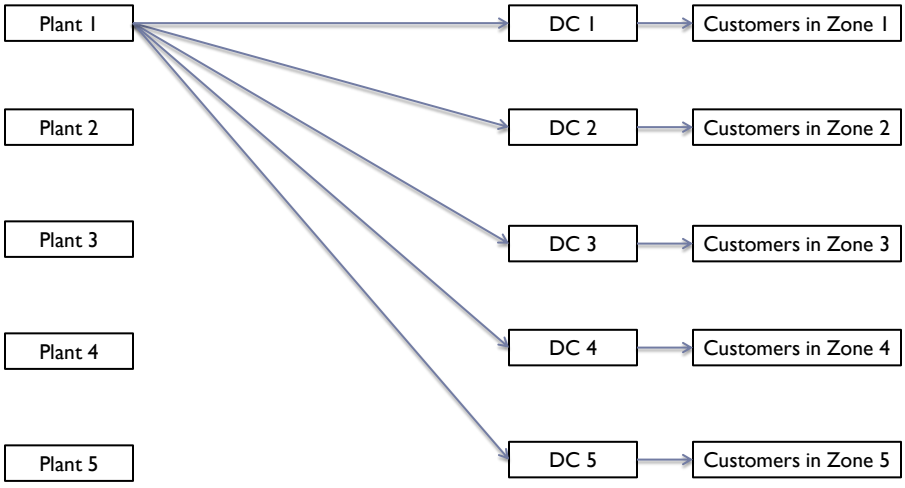
- Equipment, process technology, training, overhead, marketing and distribution

- Scale economies
  - Product variety ➔ Higher costs of switch and adaptation as well as reduced productivity
  - Solution: product-variety based production
- Scope economies
  - Product variety ➔ Smaller delivery size and more frequent deliveries for each variety ➔ Transportation costs and customer dissatisfaction
  - Solution: customer-order based delivery

Order-based Production and Inter-unit Sourcing



Variety-based Production and Inter-unit Sourcing



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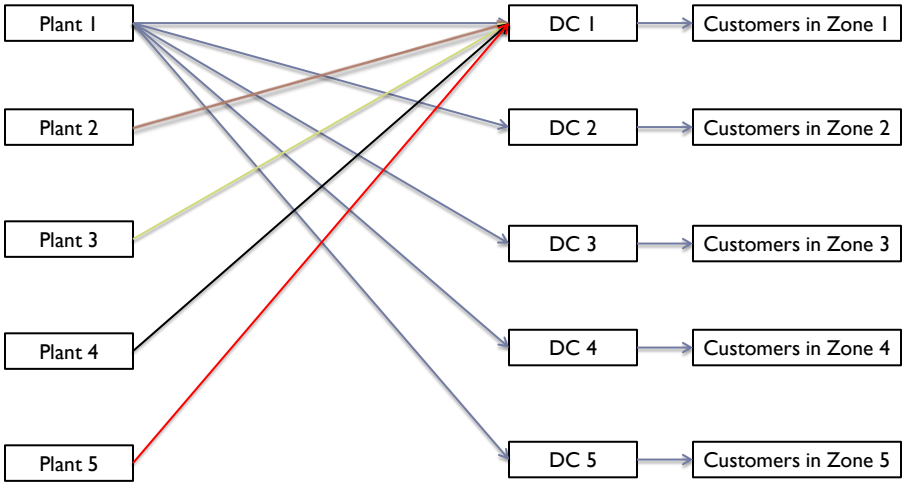
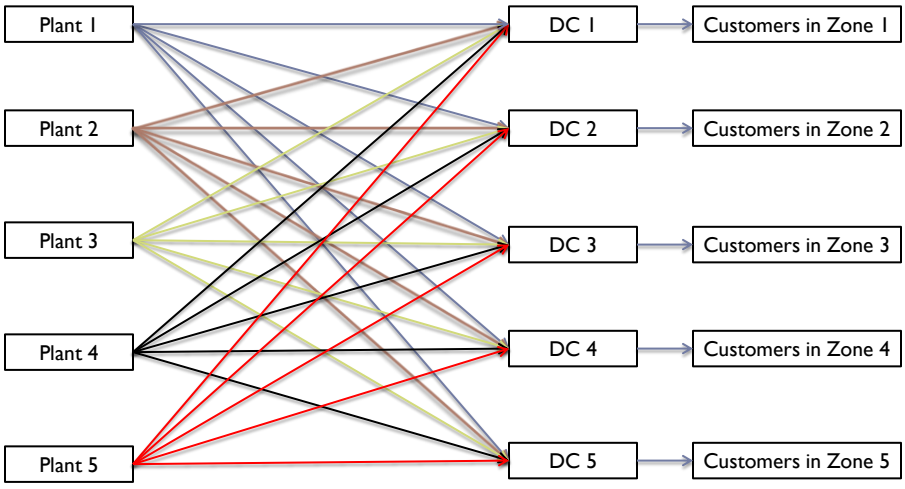


Variety-based Production and Sourcing Complexity



Product Variety and Sourcing Complexity

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Scale economies

- Product variety ➔ Higher costs of switch and adaptation as well as reduced productivity
- Solution: product-variety based production

Scope economies

- Product variety ➔ Smaller delivery size and more frequent deliveries for each variety ➔ Transportation costs and customer dissatisfaction
- Solution: customer-order based delivery

Hypothesis 1: Product variety increases the complexity of inter-unit sourcing relationships.

Sourcing Complexity and Coordination

Complexity creates coordination challenges

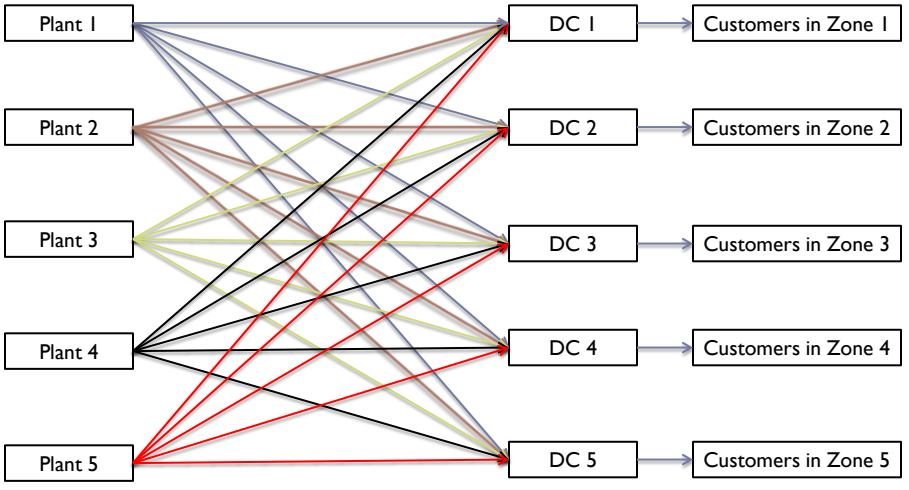
- In general, complexity creates coordination challenges at multiple levels within organizations (Ethifaj & Levinthal 20014,Lenox et al. 2006, 2007, Levinthal 1997, Rivkin, Siggelkow 2002)
- In particular, sourcing complexity increases logistical, scheduling, quality evaluation, and change costs (Miller and Vollmann 1985)

Sourcing complexity increases the costs of information processing

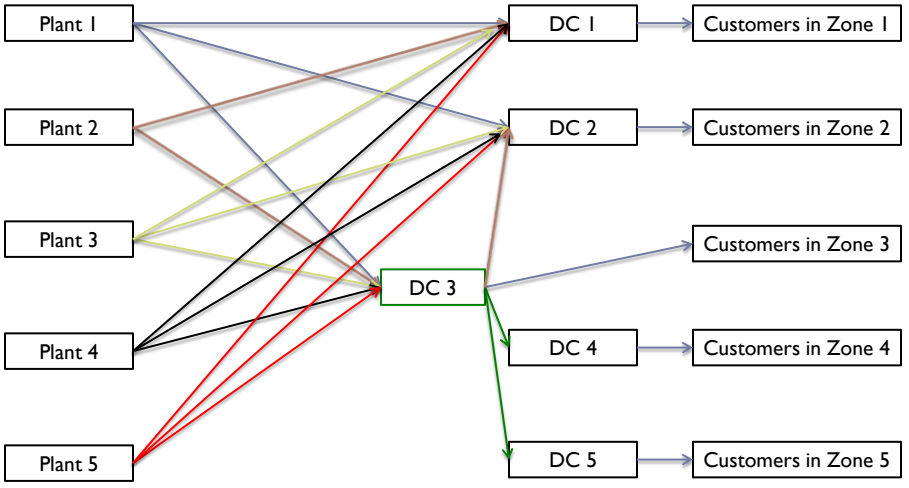
- Communication costs (Arrow 1974, Becker & Murphy 1992)
- Decision error (Levinthal 1997, Sutherland 1980)

Hypothesis 2: Complex inter-unit sourcing relationships worsen coordination performance.

Variety-based Production and Sourcing Complexity



Product-variety-based Production and A Sourcing Hub



Hierarchical Sourcing and Bottleneck of Coordination

Benefits of a hierarchical sourcing structure

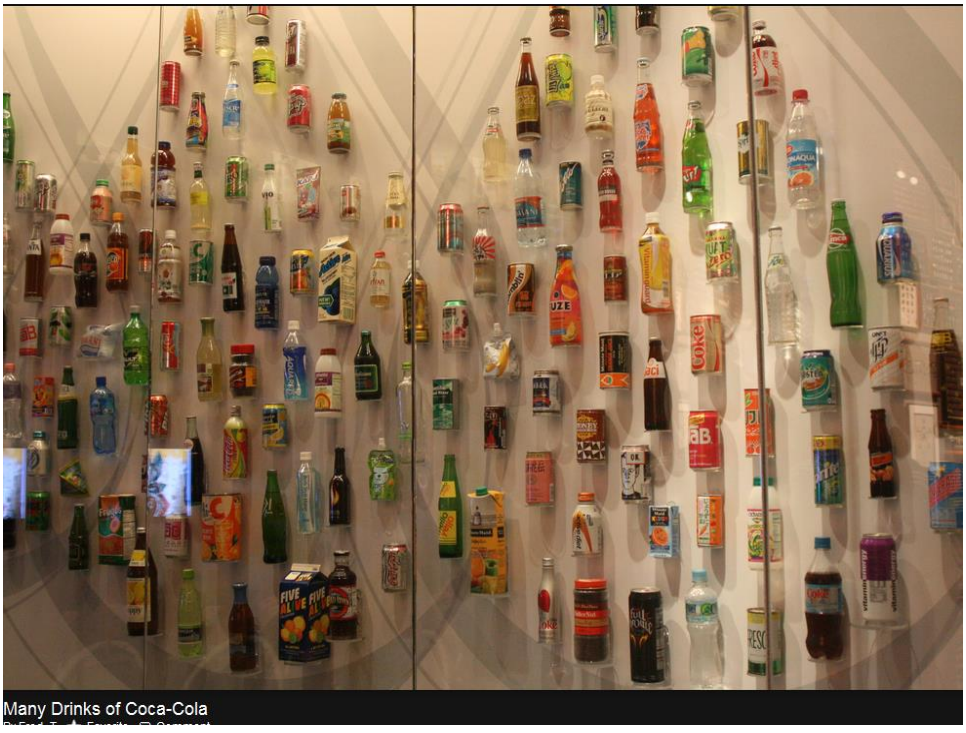
- Intermediary coordination
- Reduced complexity for the sourcing network

Disadvantage of a hierarchical sourcing structure

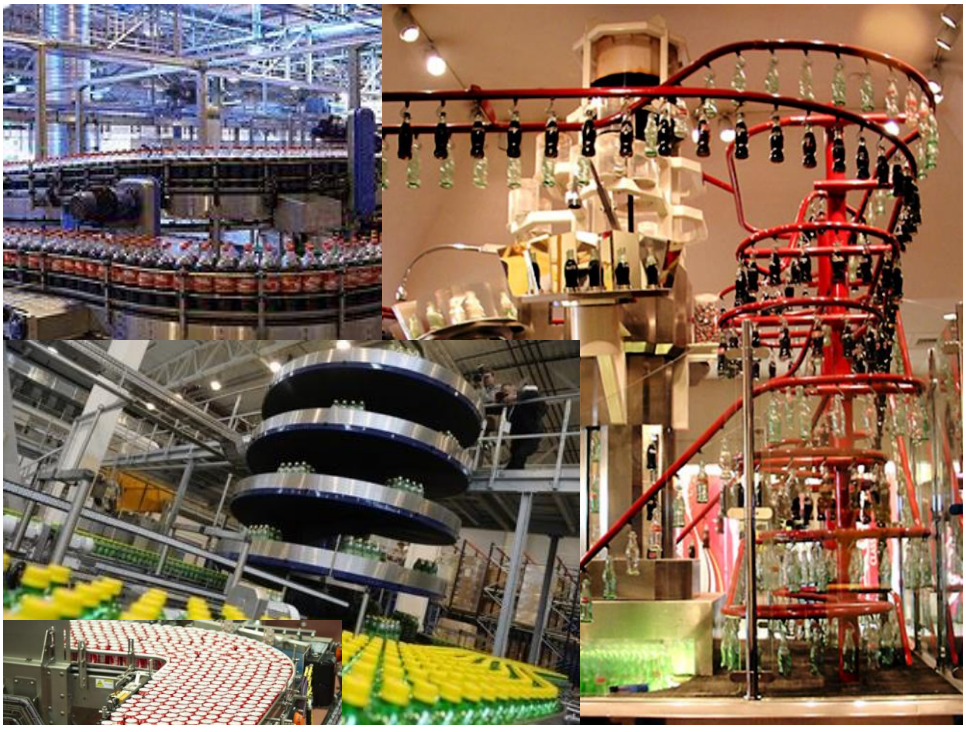
- Coordination burden on the hubs
- Bottlenecks of coordination
  - A bottleneck obstructs a flow, thereby limits system performance (Baldwin 2014)

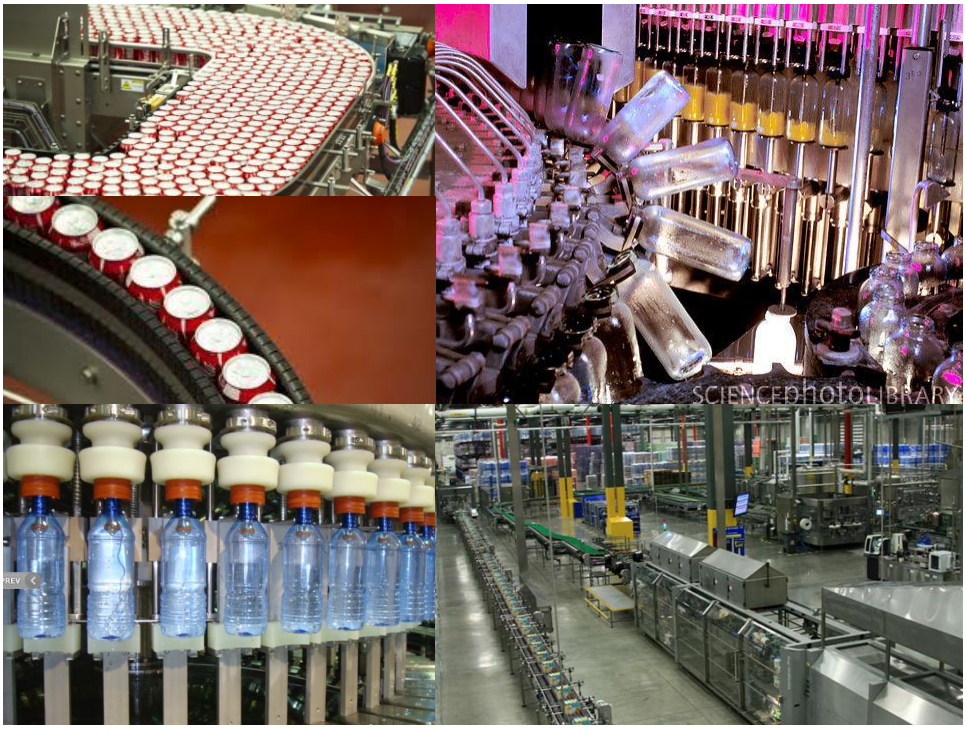
Hypothesis 3: Controlling for the complexity of inter-unit sourcing relationships, units experience worse coordination performance when they source through a hub.

The Soft Drink Industry



Many Drinks of Coca-Cola

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Doritos
Lays
pepsi

Sample & Variables

DC-SKU-period-level observations

- All distribution centers (DCs) within North America: >200 DCs
- ~2,000 SKUs (>600 brand) & 13 four-week periods (2010-2011)
  - ~ 80,000 DC—SKU pairs & ~1 million DC—SKU—periods

Variables

- Stockouts (1,0): ~ 27%
- Variety: Number of brands carried by the DC
- Sourcing Complexity: Number of other units (DCs or plants) from which the focal DC receives products
- Sourcing form a hub (1,0): Sourcing from a DC that also supplies to at least three other DCs
- CVs: sales quantity, days of inventory, demand forecast accuracy, season dummies, etc.

Table 3: Product Variety and Sourcing Complexity

DV=Sourcing Complexity	**(1)**	**(2)**	**(3)**
Product variety			
- Number of brands	0.156***	0.028***	
	[0.012]	[0.010]	
- Number of SKUs			0.002***
			[0.001]
Sales		0.361**	0.443***
		[0.082]	[0.092]
Sales volatility		0.254	0.294
		[0.864]	[0.861]
Beginning Inventory		-0.005	-0.004
		[0.005]	[0.005]
Forecasted sales		-0.178	-0.125
		[0.247]	[0.249]
DC FE	No	Yes	Yes
Season FE	Yes	Yes	Yes
Observations	3,430	3,430	3,430
Adjusted R^2	0.05	0.91	0.91

Table 4: Sourcing Complexity and Stockouts

DV= Stockout (1,0)	(1)	(2)	(3)	(4)	(5)	(6)
Product variety	0.028***	0.023***	0.025***	0.025***	0.025***	0.025***
	[0.001]	[0.001]	[0.002]	[0.002]	[0.002]	[0.002]
Sourcing Complexity						
- Number of units from which the DC receives shipments for all SKUs		0.051***	0.028***			
		[0.001]	[0.004]			
- Number of units from which the DC receives shipments for all SKUs, lagged				0.013***	0.013***	
				[0.004]	[0.004]	
- Number of units from which the DC receives shipments for all SKUs excluding sourcing units for the focal SKU, lagged						0.045***
						[0.003]
Sales	0.241***	0.233***	0.465***	0.465***	0.496***	0.496***
	[0.001]	[0.001]	[0.004]	[0.004]	[0.004]	[0.004]
Sales volatility	2.291***	2.318***	2.454***	2.454***	2.425***	2.418***
	[0.013]	[0.013]	[0.018]	[0.018]	[0.018]	[0.018]
Beginning Inventory	-0.005***	-0.005***	-0.006***	-0.006***	-0.007***	-0.007***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Forecasted sales	-0.561***	-0.570***	-0.585***	-0.586***	-0.558***	-0.557***
	[0.006]	[0.006]	[0.007]	[0.007]	[0.008]	[0.008]
Quantity received, lagged					-0.036***	-0.058***
					[0.002]	[0.002]
DC-SKU FE	No	No	Yes	Yes	Yes	Yes
Season FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	884,818	884,818	884,818	884,818	884,818	884,818
Number of DC-SKUs	79,144	79,144	79,144	79,144	79,144	79,144
Pseudo R^2	0.08	0.08	0.11	0.11	0.11	0.11

Table 5: Sourcing Complexity and Stockouts - Mechanism

	Stockout (1,0) (1)	Stockout (1,0) (2)	Stockout (1,0) (3)	Shipment Qty[a] (4)	Volitily in Shipment Qty[a] (5)
Sourcing Complexity (all SKUs)	0.018***	0.045***	0.031***	0.015***	0.006***
	[0.004]	[0.006]	[0.007]	[0.002]	[0.001]
Sourcing Complexity* Sales volatility	0.055***		0.053***		
	[0.006]		[0.007]		
Sourcing Complexity* Experience		-0.001***	-0.001***		
		[0.0002]	[0.0002]		
Product variety	0.025***	0.025***	0.025***	-0.001	0.001
	[0.002]	[0.002]	[0.002]	[0.001]	[0.001]
Sales	0.465***	0.465***	0.472***		
	[0.004]	[0.004]	[0.003]		
Sales volatility	2.249***	2.253***	2.294***	0.660***	0.122***
	[0.030]	[0.018]	[0.028]	[0.046]	[0.007]
Beginning Inventory	-0.006***	-0.006***	-0.006***	-0.007***	-0.001***
	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.000]
Forecasted sales	-0.585***	-0.585***	-0.551***	-0.708***	-0.179***
	[0.007]	[0.007]	[0.007]	[0.004]	[0.003]
DC-SKU FE	Yes	Yes	Yes	Yes	Yes
Season FE	Yes	Yes	Yes	Yes	Yes
Observations	884,818	884,818	884,818	884,818	884,818
Number of DC-SKUs	79,144	79,144	79,144	79,144	79,144
Pseudo/Adjusted R^2	0.11	0.11	0.11	0.07	0.04

[a] As percentage of forecasted sales quantity.

Table 6: Sourcing Hubs and Stockouts

DV= Stockout (1,0)	All DCs (1)	Non-hub DCs (2)	Non-hub DCs & Sole sourced SKUs (3)	Non-hub DCs (4)	IV – Stage 1 Sourcing through a hub (1,0) (5)	IV – Stage 2 Stockout (1,0) (6)
Being a hub: number of DCs the focal DC supplied to	0.006***					
	[0.002]					
Sourcing through a hub (1,0)						
For any SKU		0.414***	0.563***			
		[0.009]	[0.032]			
For any non-focal SKU				0.229***		
				[0.012]		
Predicted probability of sourcing through a hub for any non-focal SKU (1,0)						0.986***
						[0.093]
Sourcing Complexity (all SKUs)	0.018***	0.027***	0.119**	0.028***	-0.082***	0.107***
	[0.003]	[0.004]	[0.049]	[0.004]	[0.002]	[0.008]
Product variety	0.024***	0.024***	0.083***	0.025***	-0.013***	0.038***
	[0.002]	[0.002]	[0.009]	[0.002]	[0.001]	[0.002]
Sales	0.473***	0.420***	0.346***	0.460***	0.013***	0.452***
	[0.003]	[0.004]	[0.011]	[0.004]	[0.002]	[0.004]
Sales volatility	2.409***	2.457***	2.151***	2.451***	1.368***	1.105***
	[0.017]	[0.018]	[0.050]	[0.018]	[0.022]	[0.129]
Beginning Inventory	-0.006***	-0.005***	-0.005***	-0.006***	-0.005***	-0.001**
	[0.0001]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Forecasted sales	-0.551***	-0.557***	-0.625***	-0.583***	-0.151***	-0.437***
	[0.007]	[0.008]	[0.022]	[0.007]	[0.012]	[0.016]
Monthly increase in gasoline price in the state					-0.454***	
					[0.079]	
DC-SKU FE	Yes	Yes	Yes	Yes	Yes	Yes
Season FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,011,792	884,818	100,154	884,818	884,818	884,818

Conclusions

Research questions:

- *How does product variety affect operational **complexity**?*
- *How does **organizational structure** affect the efficiency of a product proliferation strategy?*

Main findings:

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- Complexity sourcing relationships ➔ coordination challenges ➔ lower level of service (LOS)
- A hierarchical structure with sourcing hubs reduces complexity for the entire network but gives rise to coordination bottleneck at these hubs and worsens LOS for units sourcing through these hubs

Contributions:

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  - Variety ➔ Coordination challenges ➔Lower performance
- Complexity
  - Source of interdependencies and challenges of structural design
  - Locus of coordination and bottlenecks in complex systems
- Stockouts (OM)
  - Coordination challenges *between* organizational units


Thank you!