

P O M S

Product Operations Management Society

# Product Complexity and Mode Choice in Global Product Development

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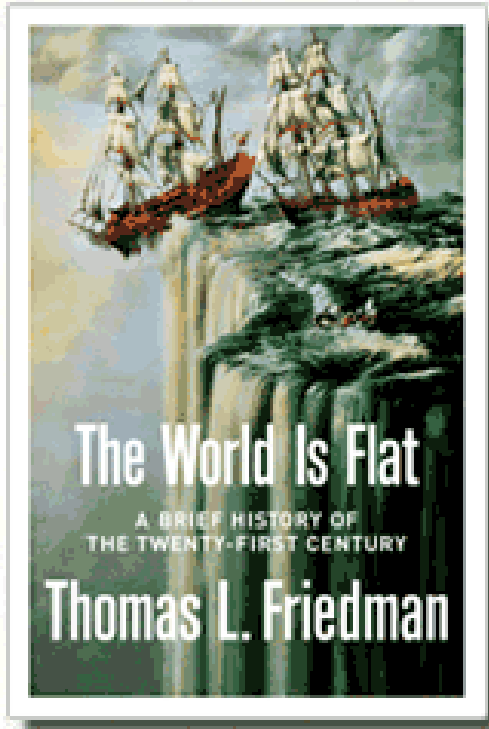
With Prof. Warren Seering & Dr. Eric Rebentisch

# Today's presentation agenda

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- Research motivation
- Key research question
- Literature and hypotheses
- Research methods
- Analysis and results

# Research motivation



“Increasingly, products used in developing markets will be **designed by local teams** who understand their application” GE 2005 SEC Filings



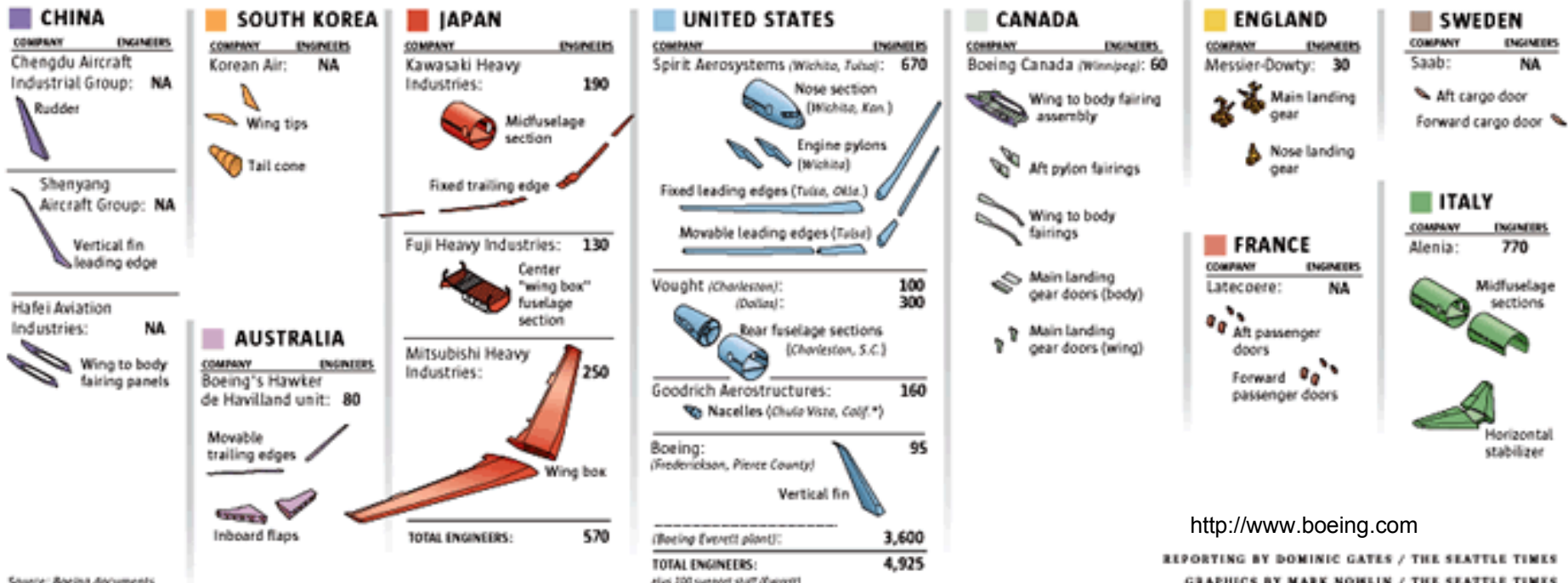
“The **new** practice of Global Product Development”  
(Eppinger and Chitkara, Summer '06)

**MIT Sloan**  
Management Review



# Who makes the parts and where the engineering jobs are

Numbers of engineers are projections for the end of 2005 made by Boeing's first-tier partners, and may not include all engineering specialties. Production workers are not included.



<http://www.boeing.com>

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# Key research question

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How does module complexity affect the mode choice in global product development?

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# Modes of global product development

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- **Captive Offshore**
  - In captive offshoring, the manufacturer owns the product development resources in the foreign country (Eppinger & Chitkara, 2006; p. 26)
- **Global Outsource**
  - In global outsourcing, the product development is done in a foreign country by separate “unaffiliated suppliers or outside engineering firms” (Cusumano & Nobeoka, 1990; p. 29).
- **Global Partnership**
  - Global partnerships are based on long term relationships, an ownership stake, joint venture or strategic alliance (Dyer, 2000)



# Product characteristics that influence mode choice in manufacturing

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- Transaction cost theory: (Coase, 1937; Williamson, 1981)
  - Complexity (Masten 1984; Novak and Eppinger 2001)
  - Specificity (Klein, 2004; Pisano 1990)
  - Uncertainty (Levy, 1985; Walker & Weber, 1984)
  - Opportunism (Williamson, 1993; Sheffi, 2005)
- Resource-based theories: (Penrose, 1959; Wernerfelt, 1995)
  - Capability (Ulrich & Ellison, 2005; Prahalad & Hammel, 1990)
  - Importance to strategy (Venkatesan, 1992; Manders & Brenner, 1995)
  - Financial investments (Tayles & Drury, 2001)
  - Economies of scale (Cachon & Harker, 2002)
  - National culture (Belderbos, 2003; McLaren, 2000).

# Complexity and manufacturing mode choice

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- Definitions of complexity
  - Various definitions (Kim & Wilemon, 2003)
- Complexity influence on manufacturing mode choice
  - No-influence – Anne (2007)
    - Metal firms' production and tooling services
    - Performance uncertainty
  - In-source – Novak and Eppinger (2001)
    - automobile parts
    - Number of parts, interactions and technological novelty
  - In-source – Masten (1984)
    - aerospace contracts
    - uncertainty

# Research hypotheses

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- I. Worldwide, high module complexity increases the likelihood of product development through the captive offshore mode relative to the global outsource mode.
- II. Worldwide, high module complexity increases the likelihood of product development through the global partnership mode relative to the global outsource mode
- III. Worldwide, high module complexity increases the likelihood of product development through the captive offshore mode relative to the global partnership mode.

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# 18 companies in the study



GE Energy



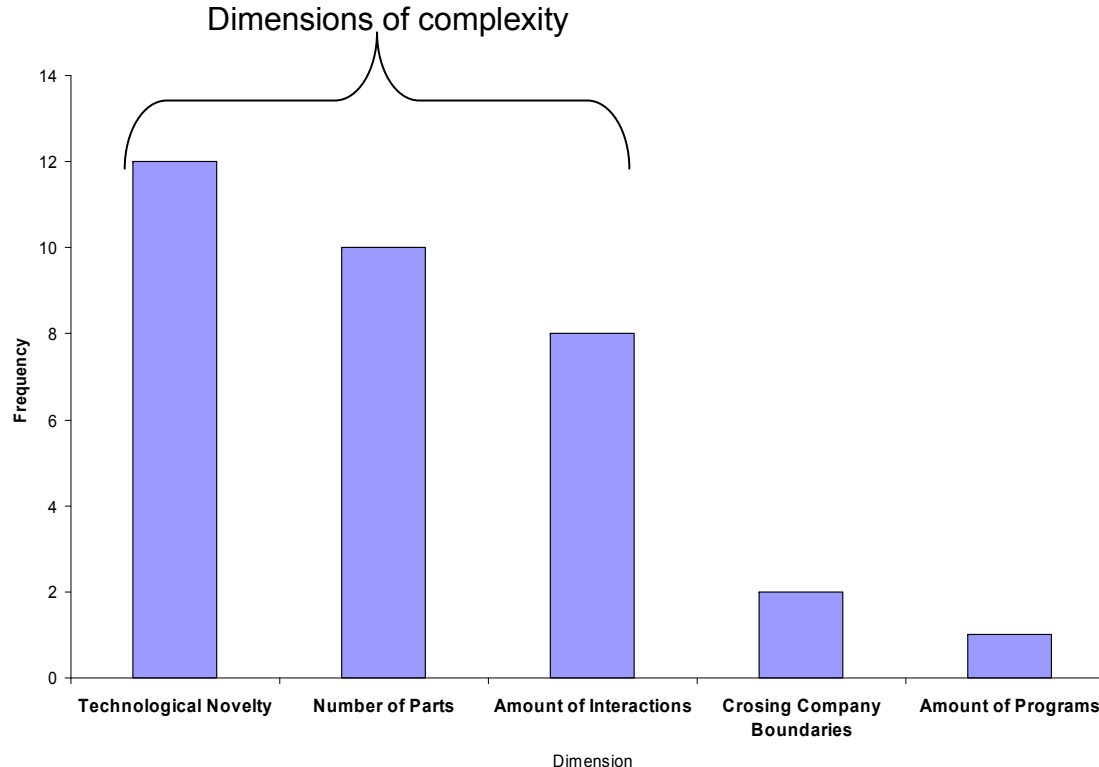
# Phase I: Total number of interviewees and their ranks

Interviewee rank	Number of interviews
Group Vice Presidents / CTOs	3
Vice Presidents	3
Directors	19
Chief Engineers / General Managers	5
Managers	11
Supervisors	14
Engineers	25
<b>Total</b>	<b>80</b>

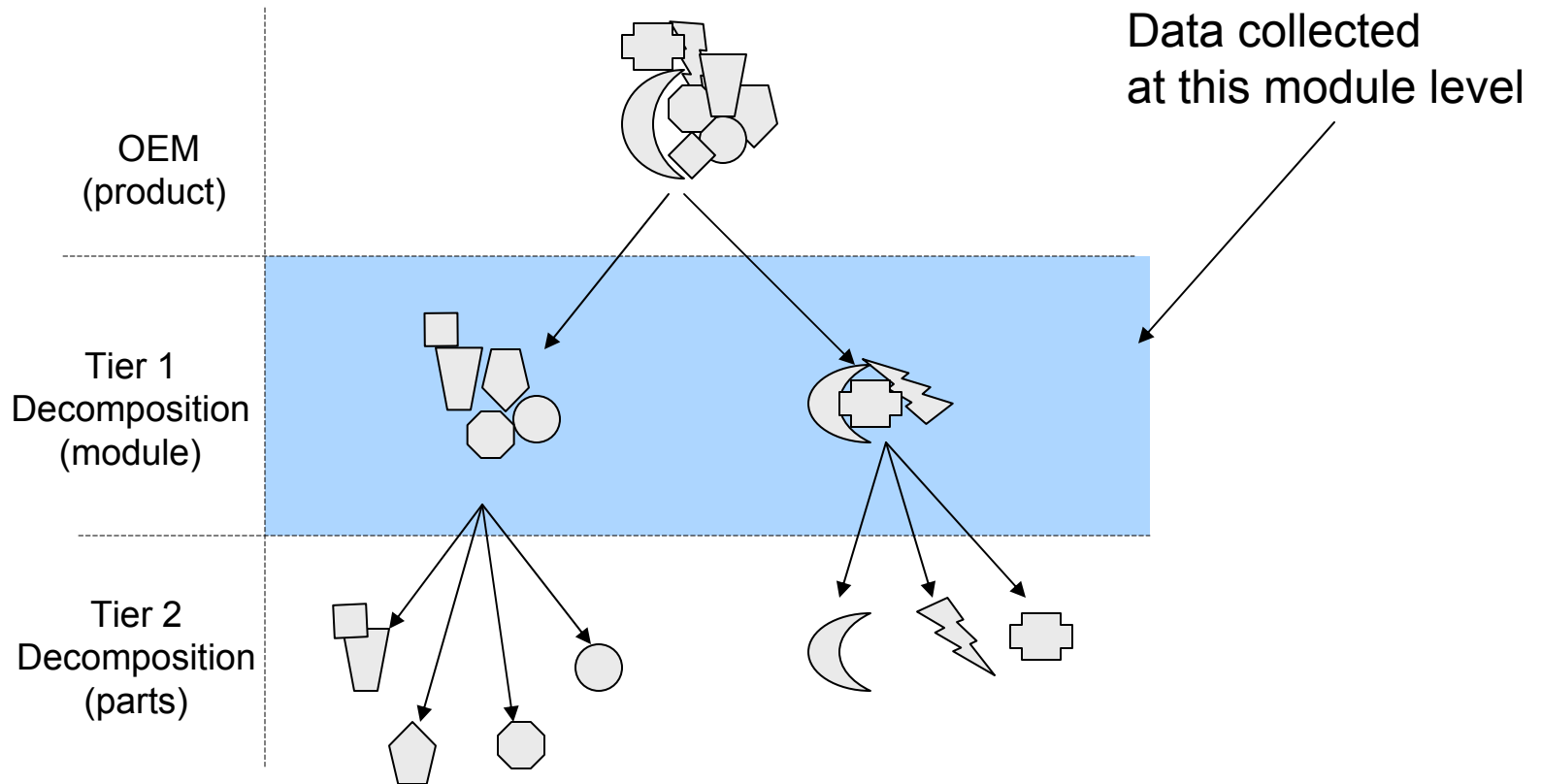
- Interviews duration ranged from 30min. to 3 hours depending on interviewee seniority and stage in the research. Interviews got shorter as we transitioned from open-ended to semi-structured interviews
- We collected the data over 15 months, of which the first 500hours (3 months) were spent working in a high tech, clean-energy globally distributed product development project
- About half of the initial interviews came from the first company, and the other half came from the other 17 companies. This strategy allowed us investigate the replicability of the findings from the first company

# Phase I: Empirical assessment of the definition of complexity

Question asked: What makes module XYZ complex from a global product development point of view



# Phase II: Schematic product decomposition for gathering data





# Phase II: Module level research design

- **Quasi-experimental design**
  - Gather module level data for modules developed outside program home country
- **Population**
  - All available modules
- **Sampling strategy**
  - Quota sampling
  - Beyond first company, we limited each company to at most 12 modules. We asked for 12, got an average of 6 depending on enthusiasm in the study
- **Sample**
  - All available electromechanical modules
- **Sample size**
  - We obtained 156 modules in total. From these, we could not use 38. Of the 38, 23 had missing information, while the other 15 were decomposed beyond tier 2 to extent of discussing fasteners.
  - We had a total of 118 usable modules, developed in 25 countries

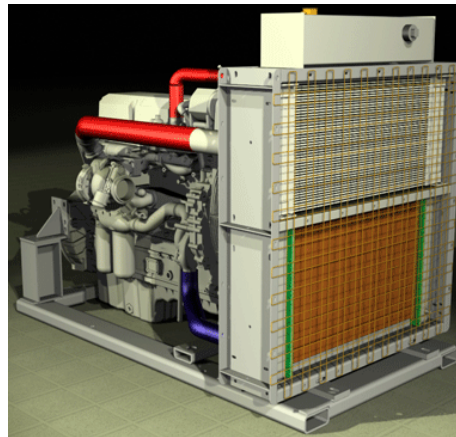
# Phase II: Module level research methods

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- Semi-structured interviews
- Internal documents
- Data template
  
- Key module variables
  - Nature of the development relationship
  - Complexity dimensions
  - Specificity (uniqueness)
  - Importance to strategy
  - Designer's capability
  - Development location

# Phase II: Example of data gathered for each of 118 modules

Module characteristic	Raw Value	Coded Value
Module name	Cooling Package	
GPD mode	Global Outsource	3
Number of parts	100	2
Technological novelty	New to our company locally	2
Interactions	We integrated them, they worked on same contract	5
Specificity	21%-30%	3
Designer's Capability	As good as ours	2
Importance to strategy	Its complimentary but not critical	2



# Phase II: Snippet of the module level data

\*testint.sav [DataSet 1] - SPSS Data Editor

File Edit View Data Transform Analyze Graphs Utilities Add-ons Window Help

95 : RecordID Otis3 Visible: 153 of 153 Variables

	RecordID	Country	Modulename	Developername	Mode	mode_Code	Importance	Importance_code	TechNovelty	TechNoveltyCode
79	FLK2	UK	CO monitor	City Technolo...	Supplier	3	Its not necessary to our strategy	1	New to our company worldwide	
80	FLK3	Switzerland	Temperature monitor	Sensirion	Supplier	3	Its not necessary to our strategy	1	New to our company worldwide	
81	FLK4	Canada	Air MeterFirmware	BW Technolo...	Partner	1	It's complementary but not criti...	2	New to the world	
82	FLK5	Taiwan	Humidity monitor	CHY Firemate	Partner	1	Its not necessary to our strategy	1	New to our company worldwide	
83	FLK6	Taiwan	Pressure Differential ...	CHY Firemate	Partner	1	Its not necessary to our strategy	1	New to our industry worldwide	
84	FLK7	China	Milliamp Sensor	Fluke	Self	2	It's critical to our strategy	3	New to the world	
85	FLK8a	China	Radiometry Module	Fluke	Self	2	It's critical to our strategy	3	New to our industry worldwide	
86	FLK8b	Germany	Radiometry Module	Fluke	Self	2	It's critical to our strategy	3	New to our industry worldwide	
87	FLK9	India	Radiation Sensor mod...	Larsen & Toubro	Partner	1	It's complementary but not criti...	2	New to the world	
88	H1	Mexico	A350 work package 5...	Honeywell	Self	2	critical	3	Not new at all	
89	H2	Mexico	Ozone converter prod...	Honeywell	Self	2	critical	3	New to our industry worldwide	
90	Otis1	Germany	buffer	acla	Supplier	3	Its not necessary to our strategy	1	Not new at all	
91	Otis10	China	sheaves	China	Supplier	3	Its not necessary to our strategy	1	Not new at all	
92	Otis11	South Korea	ropes	South Korea	Supplier	3	Its not necessary to our strategy	1	Not new at all	
93	Otis12	Japan	ropes	Japan	Supplier	3	Its not necessary to our strategy	1	Not new at all	
94	Otis2	Germany	machines	wittur	Partner	1	It's complementary but not criti...	2	New to our company locally	
95	Otis3	Spain	rails	Savera	Supplier	3	Its not necessary to our strategy	1	Not new at all	
96	Otis4	US	entrances	Otis	Self	2	It's critical to our strategy	3	Not new at all	
97	Otis5	China	fixtures	China inc	Partner	1	It's complementary but not criti...	2	New to our company locally	
98	Otis6	US	controls	Otis	Self	2	It's critical to our strategy	3	New to our company worldwide	
99	Otis7	US	drives	Otis	Self	2	It's critical to our strategy	3	New to our company worldwide	
100	Otis8	South Korea	roller guides	LG	Self	2	It's critical to our strategy	3	New to our company worldwide	
101	Otis9	China	ropes	China	Supplier	3	Its not necessary to our strategy	1	Not new at all	
102	PH1	China	carry cloth	...	Supplier	3	Its not necessary to our strategy	1	Not new at all	
103	PH10	China	Compact Power Module	...	Supplier	3	It's critical to our strategy	3	New to our company worldwide	
104	PH11	US	High Voltage ASIC Co...	...	Supplier	3	It's critical to our strategy	3	New to the world	
105	PH12	Canada	High Density Battery	...	Supplier	3	It's critical to our strategy	3	New to our company worldwide	

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# Multinomial logistics model for mode choice in GPD

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$$Mode = \beta_1 Complexity + \beta_2 Specificity + \beta_3 (Designer Capability) + \beta_4 (Importance to Strategy)$$

- Dependant variable: Modes of GPD
  - Captive offshore
  - Global outsource
  - Global partnership

# Worldwide model results

Likelihood Ratio Tests	
	Model
Intercept	0.00
Complexity	<u>0.00</u>
Specificity	0.01
Importance to Strategy	0.00
Designer's Technological Capability	0.00

Case Processing Summary (N)	
	Model
Global Partnership	20
Captive Offshore	41
Global Outsource	55
Valid	116
Missing	2
Total	118

Model Fitting Information	
	Model
Chi-Square	75.02
Model Significance	0.00

		Model Odds Ratios Results		
		Captive Offshore <sup>a</sup>	Global Partnership <sup>a</sup>	Captive Offshore <sup>b</sup>
		vs.	vs.	vs.
	Odds Ratio Estimated	Global Outsource	Global Outsource	Global Partnership
Complexity	exp( $\beta_1$ )	3.61*** (12.00)	6.06*** (14.92)	0.6 (1.31)
Specificity	exp( $\beta_2$ )	1.81*** (7.18)	1.81** (4.87)	1 (0.00)
Importance to Strategy	exp( $\beta_3$ )	2.71** (6.02)	0.69 (0.75)	3.91*** (8.55)
Designer's Technological Capability	exp( $\beta_5$ )	0.21*** (13.17)	0.43* (3.61)	0.49* (2.68)

a = reference category is the global outsource

b = reference category is the global partnership

Wald statistic for testing null hypothesis that logit is zero are shown (in parentheses)

\*p < 0.1

\*\*p < 0.05

\*\*\*p < 0.01

# Hypotheses test results summary

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- ✓ Worldwide, high module complexity increases the likelihood of product development through the captive offshore mode relative to the global outsource mode.
- ✓ Worldwide, high module complexity increases the likelihood of product development through the global partnership mode relative to the global outsource mode
- ✗ Worldwide, high module complexity increases the likelihood of product development through the captive offshore mode relative to the global partnership mode.



# Dividing countries into **mature** and **emerging** countries

<b>Mature Regions (normalized wages &gt; 1)</b>	<b>Emerging Regions (normalized wages &lt; 1)</b>
Australia	Brazil
Canada	China
Finland	India
France	Malaysia
Germany	Mexico
Ireland	Philippines
Israel	Singapore
Italy	South Korea
Japan	Taiwan
Norway	Turkey
Spain	
Sweden	
Switzerland	
United Kingdom	
United States	

Cut off between Israel and Singapore

# Mature and emerging regions model results

**Table A: Likelihood Ratio Tests**

	Mature	Emerging
Intercept	0.00	0.97
Designer's Technological Capability	0.00	0.08
Complexity	0.11	0.00
Importance to Strategy	0.00	0.88
Content Specificity	0.01	0.43
Chi-Square	63.5	25.57

**Table B: Case Processing Summary (N)**

	Mature	Emerging
Global Partnership	12	8
Captive Offshore	31	10
Global Outsource	34	21
Valid	77	39
Missing		2
Total	77	41

**Table C Models Odds Ratios**

	Odds Estimated	Mature Regions			Emerging Regions		
		Captive Offshore <sup>a</sup>	Global Partnership <sup>a</sup>	Captive Offshore <sup>b</sup>	Captive Offshore <sup>a</sup>	Global Partnership <sup>a</sup>	Captive Offshore <sup>b</sup>
		vs. Global Outsource	vs. Global Outsource	vs. Global Partnership	vs. Global Outsource	vs. Global Outsource	vs. Global Partnership
Designer's Technological Capability	exp( $\beta_2$ )	0.20*** (9.05)	0.63 (0.68)	0.31* (4.12)	0.37 (1.53)	0.19 (2.64)	1.910 (0.48)
Complexity	exp( $\beta_3$ )	1.88 (1.11)	4.17** (4.06)	0.45 (1.27)	4.11** (6.09)	10.87*** (8.91)	.380 (1.73)
Importance to Strategy	exp( $\beta_4$ )	8.04*** (7.59)	0.67 (0.44)	12.04*** (8.80)	1.36 (0.32)	1.04 (0.00)	1.31 (0.18)
Content Specificity	exp( $\beta_5$ )	2.23** (6.04)	2.32** (5.00)	0.96 (0.01)	1.36 (0.81)	1.59 (1.15)	0.86 (0.15)

a = reference category is the global outsource

b = reference category is the global partnership

Wald statistic for testing null hypothesis that logit is zero are shown (in parentheses)

\*p < 0.1

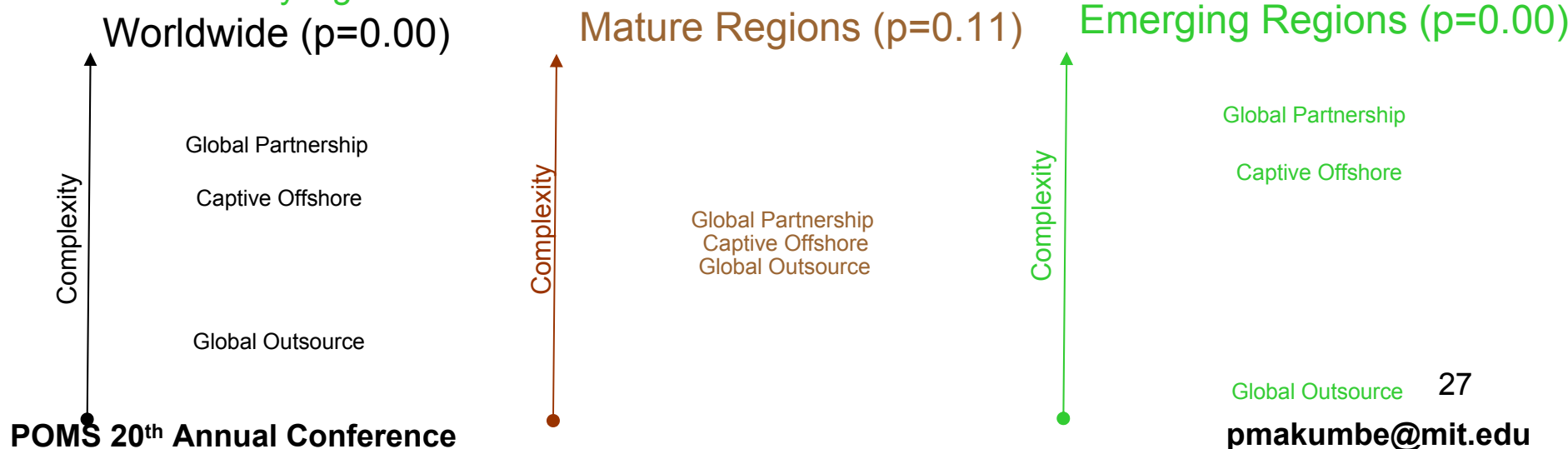
\*\*p < 0.05

\*\*\*p < 0.01

# Complexity and mode choice in GPD summary:

## *How does complexity influence mode choice in GPD?*

- Worldwide - With global outsource as the reference category, odds ratio is 3.6 times higher for captive offshore and 6 times higher for global partnership. Though the odds ratio for captive offshoring vs. global partnership is 40% lower, there is no statistical difference between the two modes with global partnership as reference.
- In mature regions, complexity is not a statistically significant differentiator among the different modes of GPD
- In emerging regions, complexity is the key differentiator among the different modes in our model. It increases the odds for captive offshore 4 times and the odds for global partnerships by 11 times higher with global outsource as the reference category. Odds for captive offshore vs. global partnership are 60% lower though they are not statistically significant.



# Academic contributions

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- Extended make/buy literature into product development : assessed the relevance of product characteristics deemed important in manufacturing in product development
- Extended the make/buy literature to include the **global** aspect of product development by investigating both mature and emerging regions: discovered surprising results
- Extended the literature beyond the dichotomous make or buy choices to include global partnerships: associated with complex products
- Empirically assessed definition of complexity in global product development : number of parts, amount of interactions and technological novelty

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# Thank You for Listening