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Disruption in the US machine tool industry: The role of inhouse users and pre-disruption component experience in firm response

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Disruption is everywhere! (1)

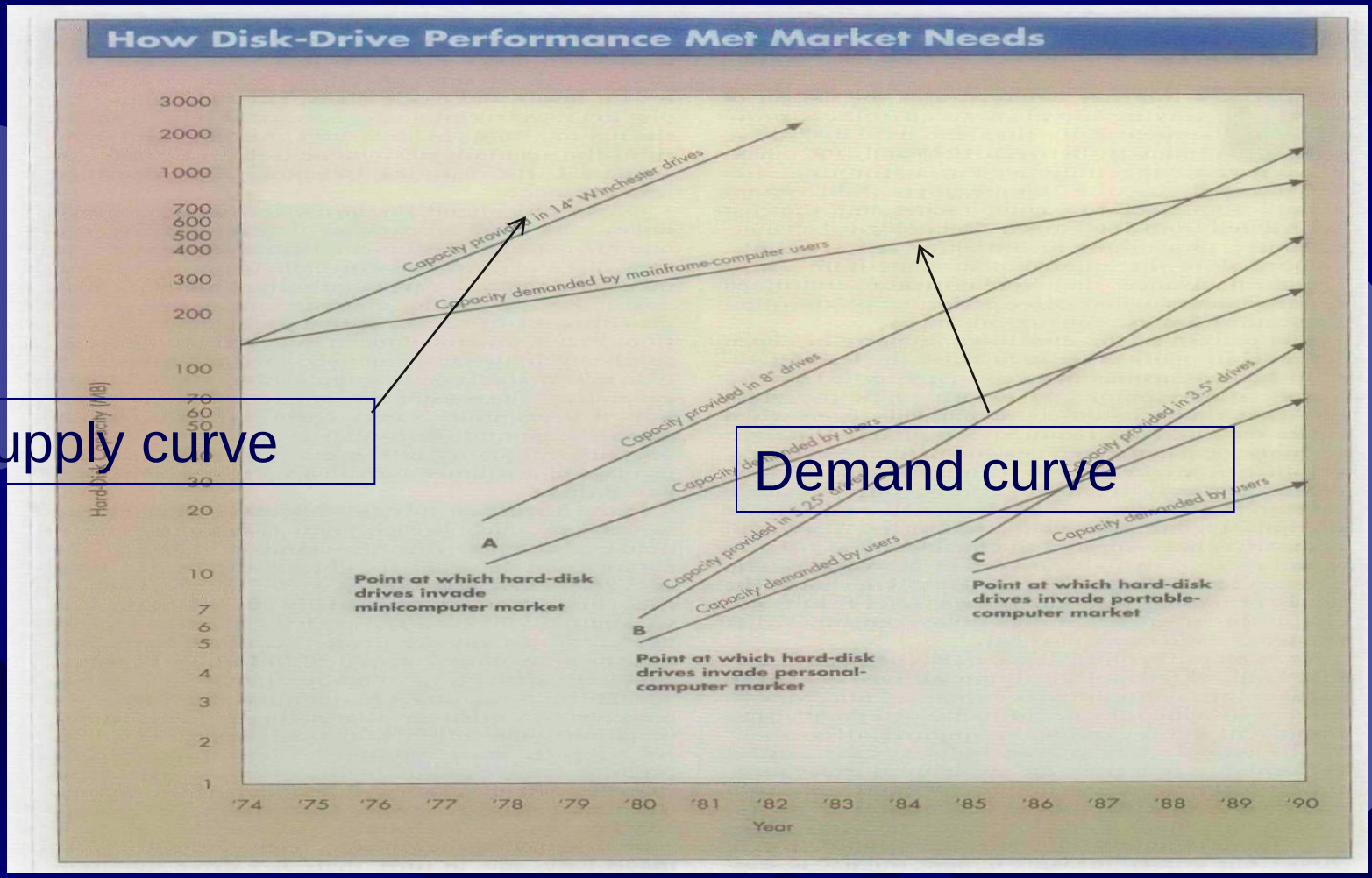
Disruption is everywhere! (2)

Disruption is everywhere! (3)

So, what is disruption? (Govindarajan and Kopalle, 2006)

- The new features offered by the disruptive innovation are not valued by the mainstream customers
- Initially, disruptive products underperform on the attributes that mainstream customers value
- The disruptive innovation is offered at a lower price than mainstream innovations
- At the time of introduction, the disruptive innovation appeals to a low-end, price-sensitive customer segment
- Over time, mainstream customers value the disruptive innovation

When does disruption really happen? Role of supply and demand



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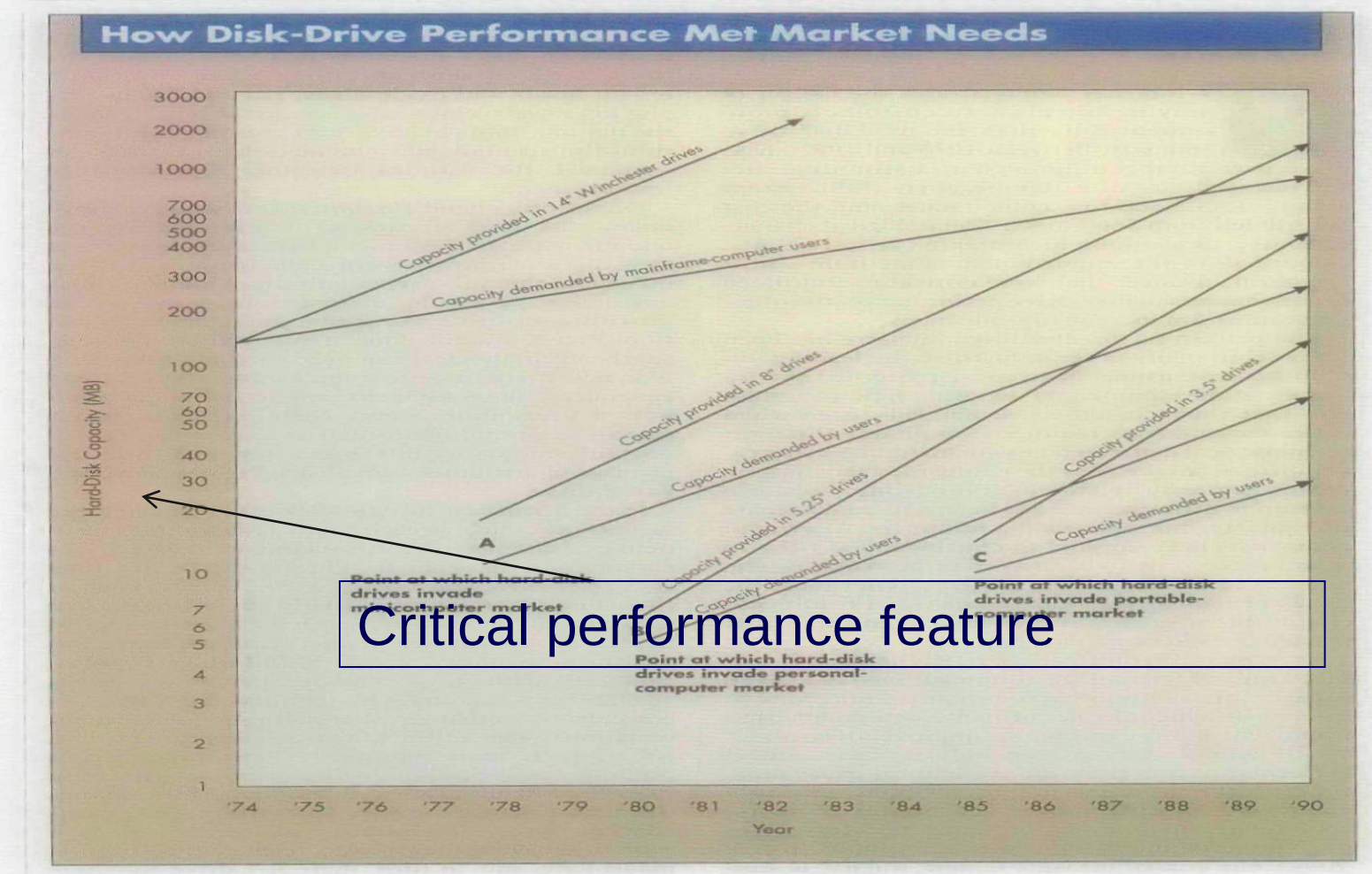

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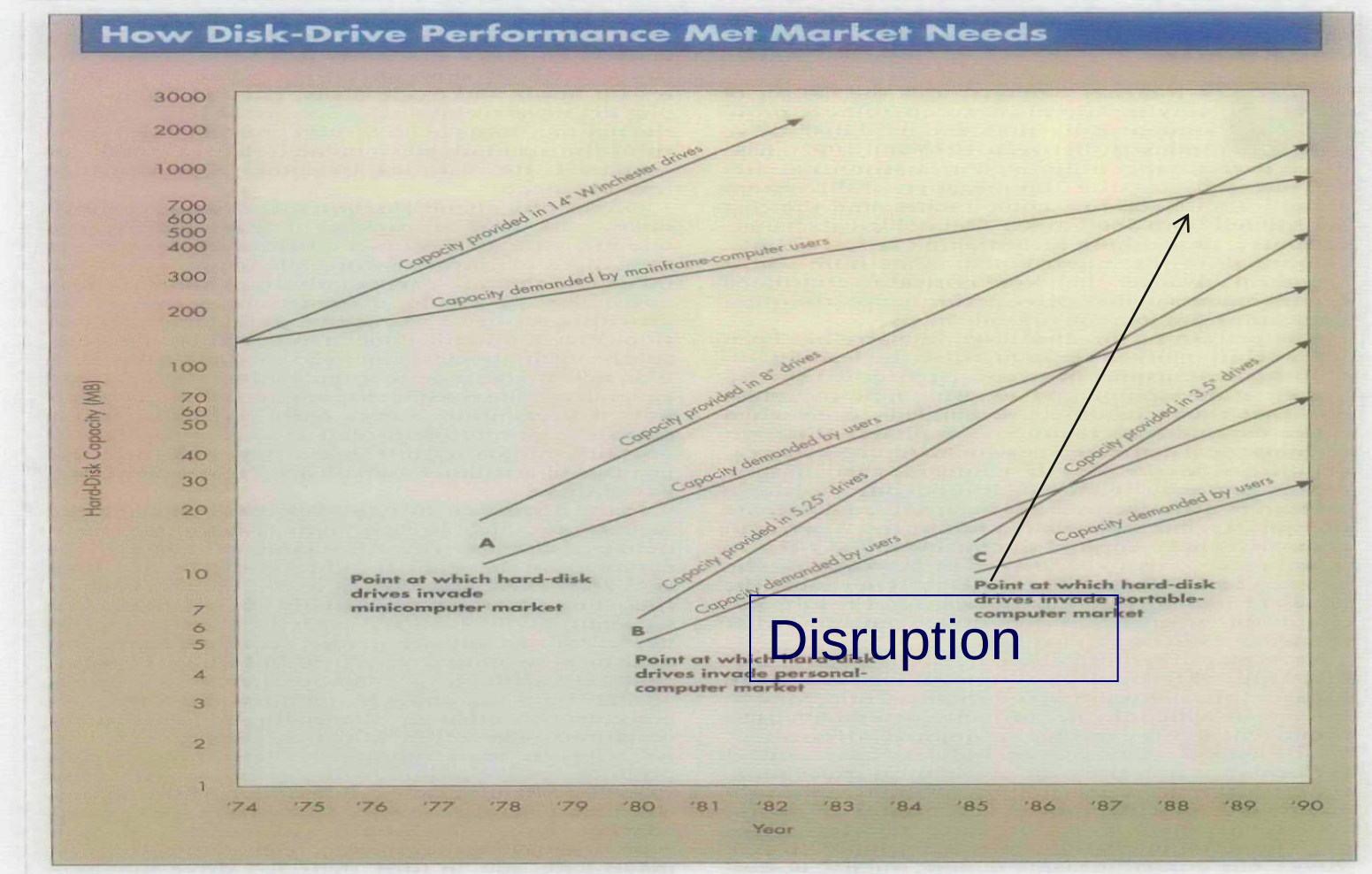


Christensen's assumptions

- "Innovator's dilemma"
  - prevents a large manufacturer, such as RCA or DEC, from responding to the disruptive threat.
  - These manufacturers either do not introduce disruptive new products,
    - or are late in introducing products that match the performance features of the disruptive products (Christensen and Overdorf, 2000).
- However, researchers (Tripsas, 1997; Christensen et al., 2011) have also provided evidence that large manufacturers,
  - Mergenthaler Linotype, Sony, and others, have successfully responded to disruptive technological changes.

Our motivation

- To understand which firms are able to avoid "innovator's dilemma"
- Two firm characteristics
  - Access to inhouse users
  - Access to relevant component knowledge
- Research question-- *"how does access to inhouse users and prior experience in the components needed to manufacture products with the disruptive technology help firms match the critical performance of the disruptive product?"*

The U.S. machine tool (MT) industry

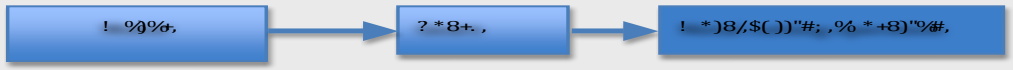
- MTs perform metal-cutting and metal-forming operations
  - Used in the manufacture of automobiles, aircraft, weapons, toys, computers, and MTs themselves!!.
- Association for Manufacturing Technology (AMT) categorizes metal-cutting MTs into 12 categories
  - Category 8 and 12 are the focus of this study

Technological innovations in the U.S. MT industry

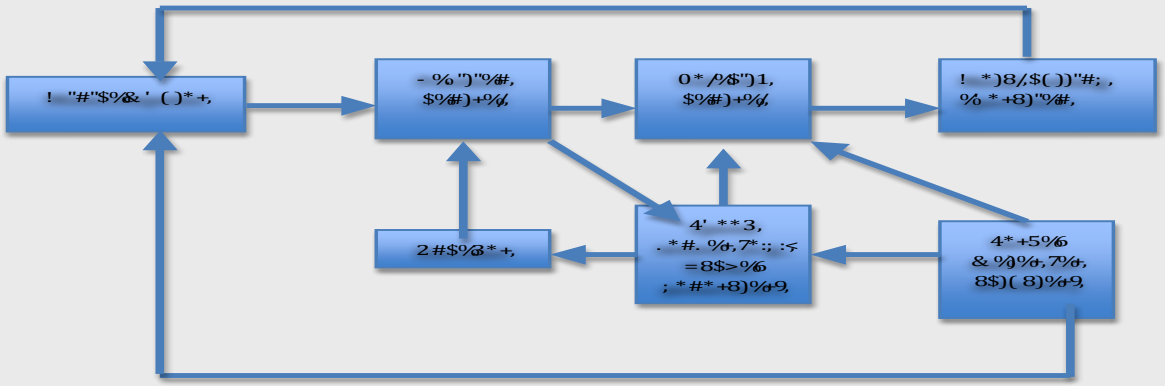
- Innovations aimed at improving the productivity of the MT users
  - 1940s: Traditionally mechanically controlled (MC) MTs
  - 1970s: Computer Numerical Control (CNC) systems
  - CNC (primarily Japanese CNC MTs) disrupts the MC MTs
- CNC provides agility to the MT
  - Agility= critical performance feature
- First CNC MTs manufactured in mid 1970s
  - Fanuc
- During the early-1980s the demand pattern of the U.S. MT industry started changing
  - From mass production to batch production

Pre-CNC and CNC Control Systems

Pre-CNC architecture:



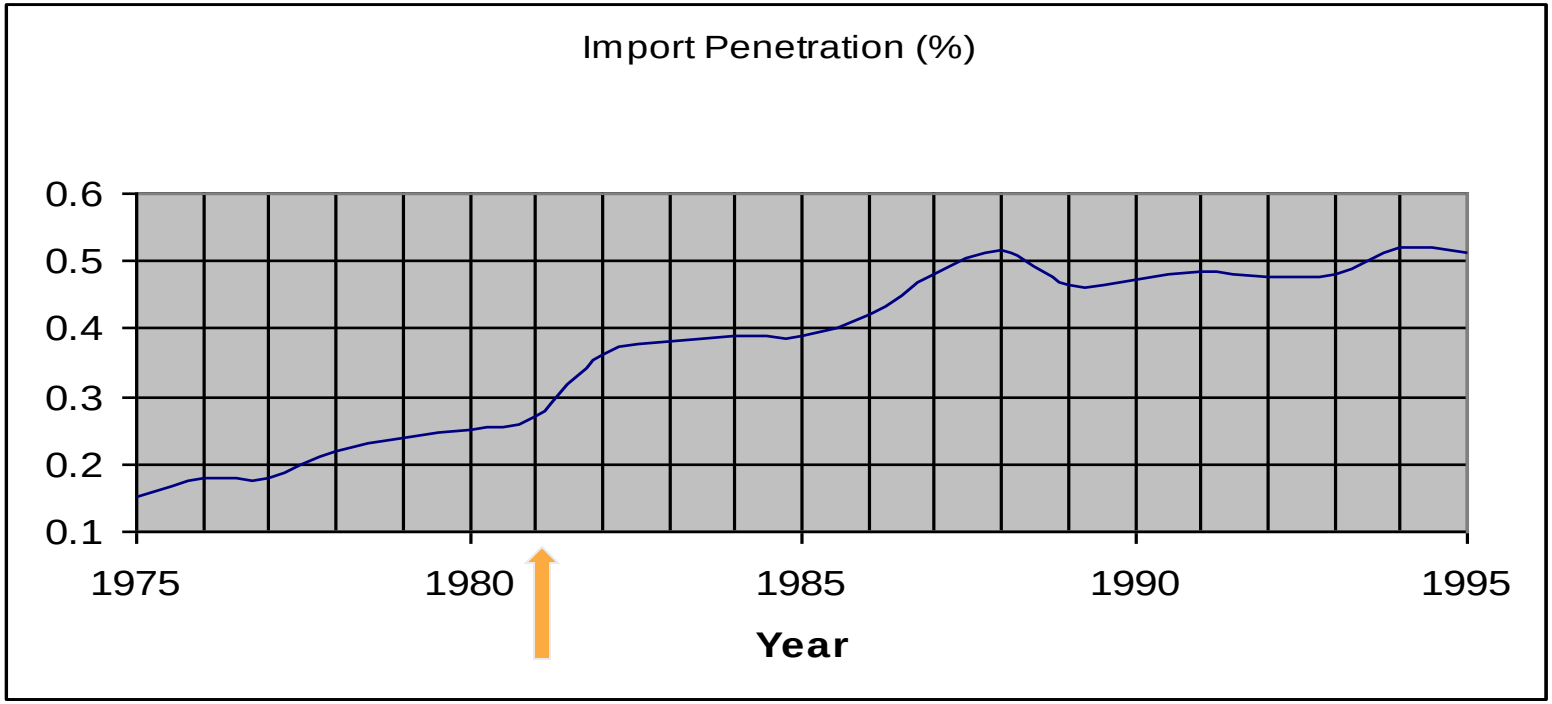
CNC Architecture:



Consequences of technological disruption in the U.S. MT industry

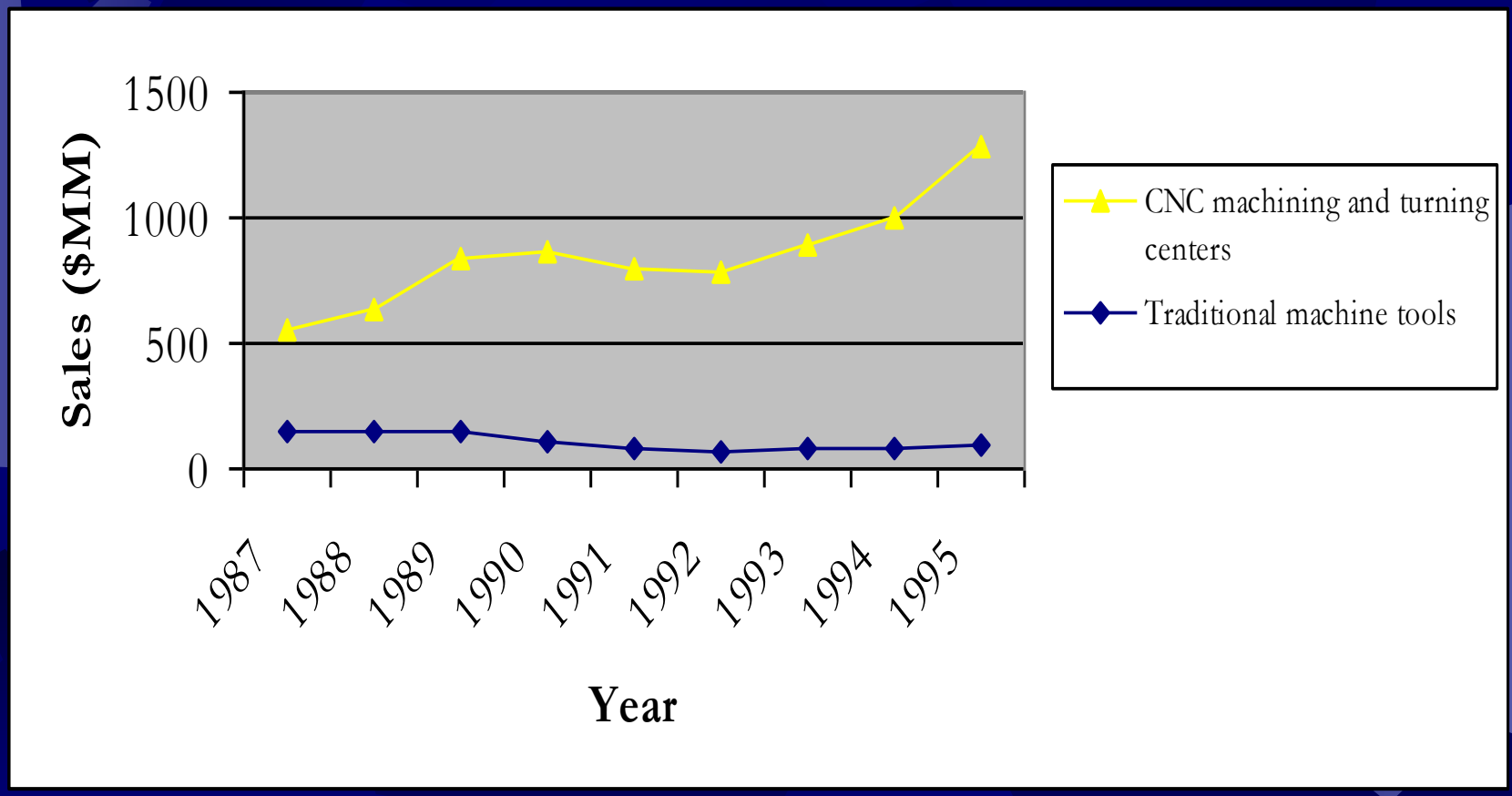
- Imports of MTs made with the disruptive CNC technology grew rapidly
  - Japanese manufacturers became the dominant players in the U.S. market
  - Majority of the U.S. manufacturers failed to survive the 1980s

Import penetration in the US MT industry

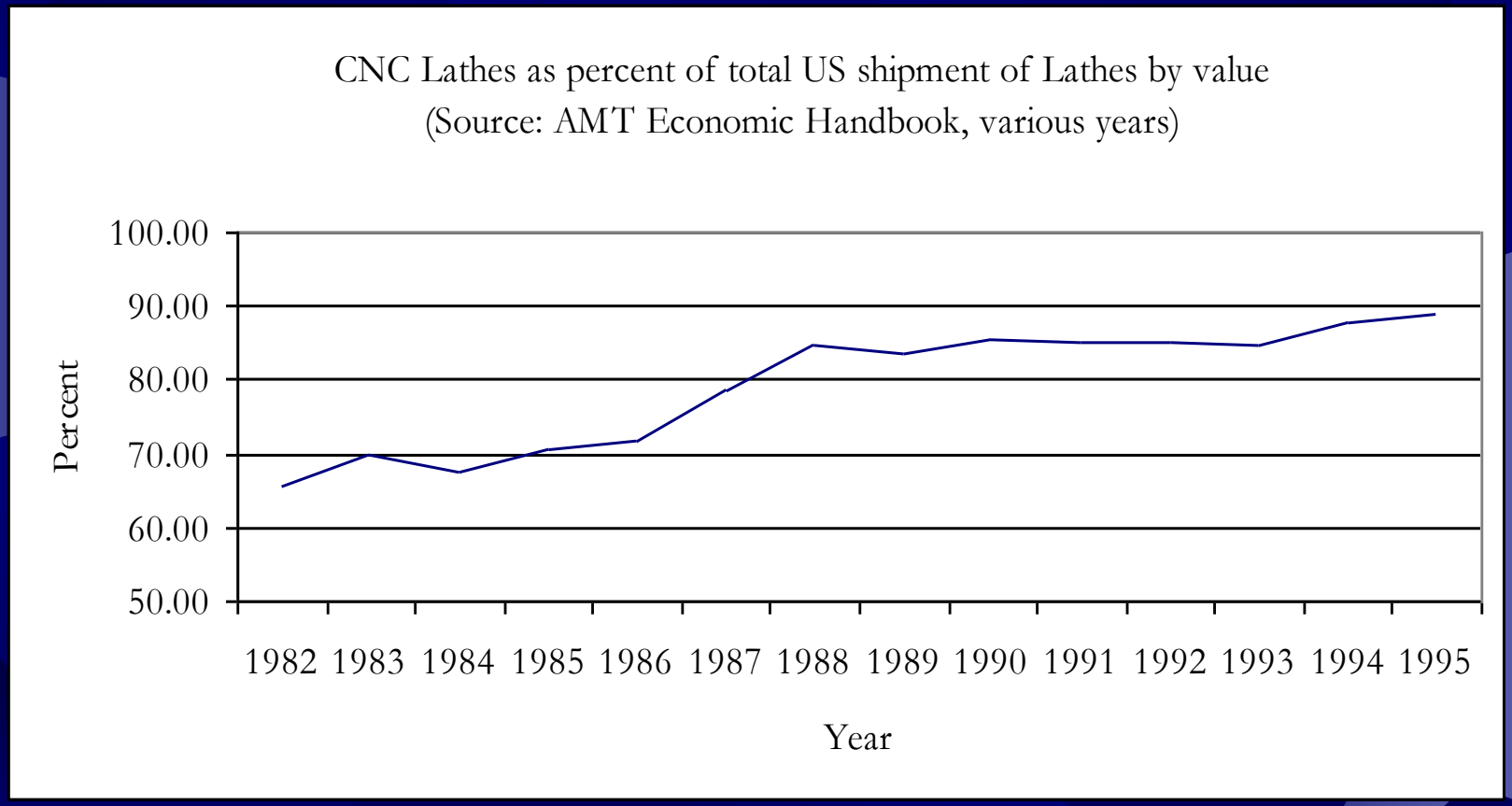


Source: AMT Economic Handbook

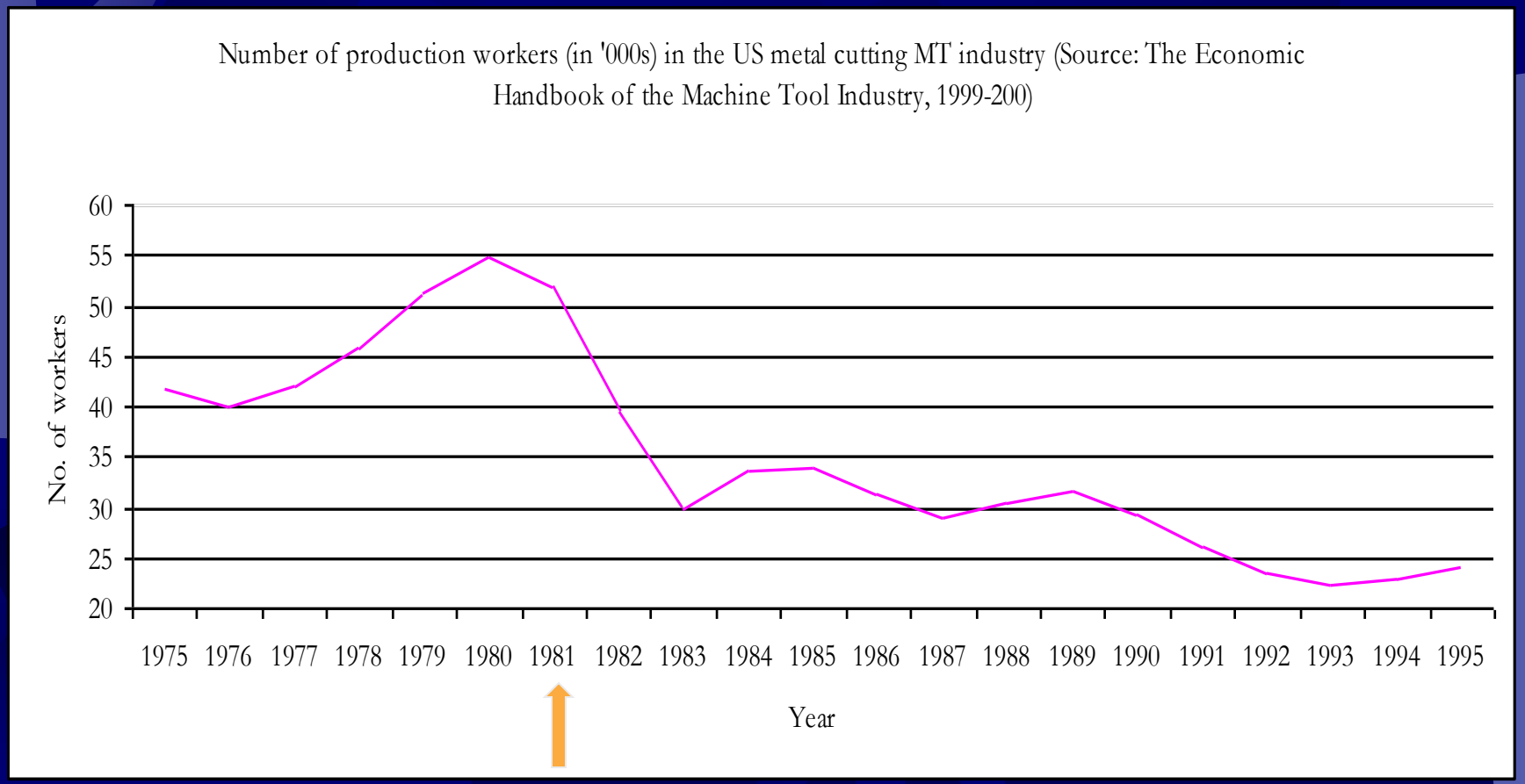
Market penetration of CNC MTs



Market penetration of CNC lathes



Change in the number of production workers in the U.S. metal cutting industry



Data: sources and description

- AMT Members' Directory: 1975-1987
- American Machine Tool Distributors' Association (AMTDA) Membership Directory, 1975-1987
- Huebner's Directory, Ward's Industrial Directory, Million Dollar Directory, D&B Metalworking Handbook, Society of Manufacturing Engineer's Handbook
- American Machinist (all issues from 1975-1987)
- Manufacturers' flyers

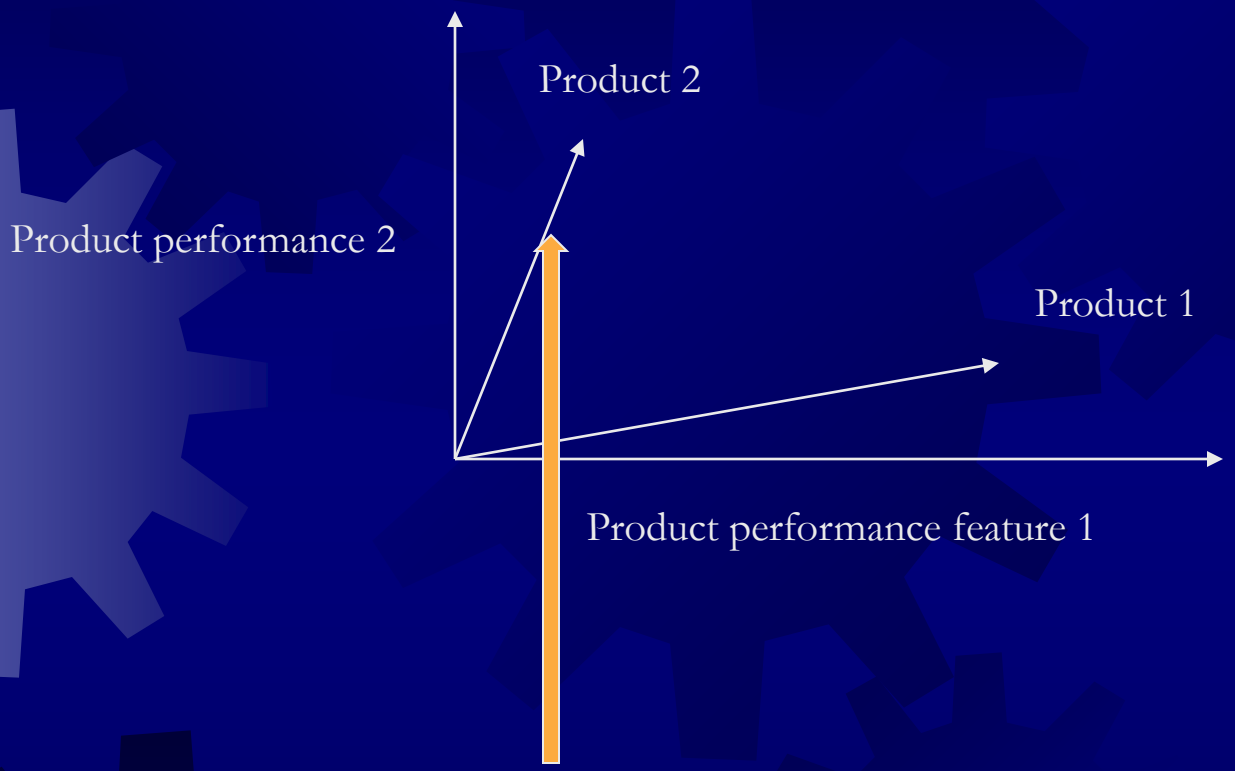
- Andy Ashburn (late ex-Editor, American Machinist), Tony Bratkovich (Engineering Director, AMT), Joe Jablonowski (Editor, Metalworking News), Ralph Nappi (President, AMTDA) and Mark Rogo (CEO, Morton Machinery)

- All MTs introduced by 45 American firms from 1975-1987
- Time line:
  - 1975-1980: *Pre-disruption period.*
  - 1981-1987: *Disruption period*

Operationalization

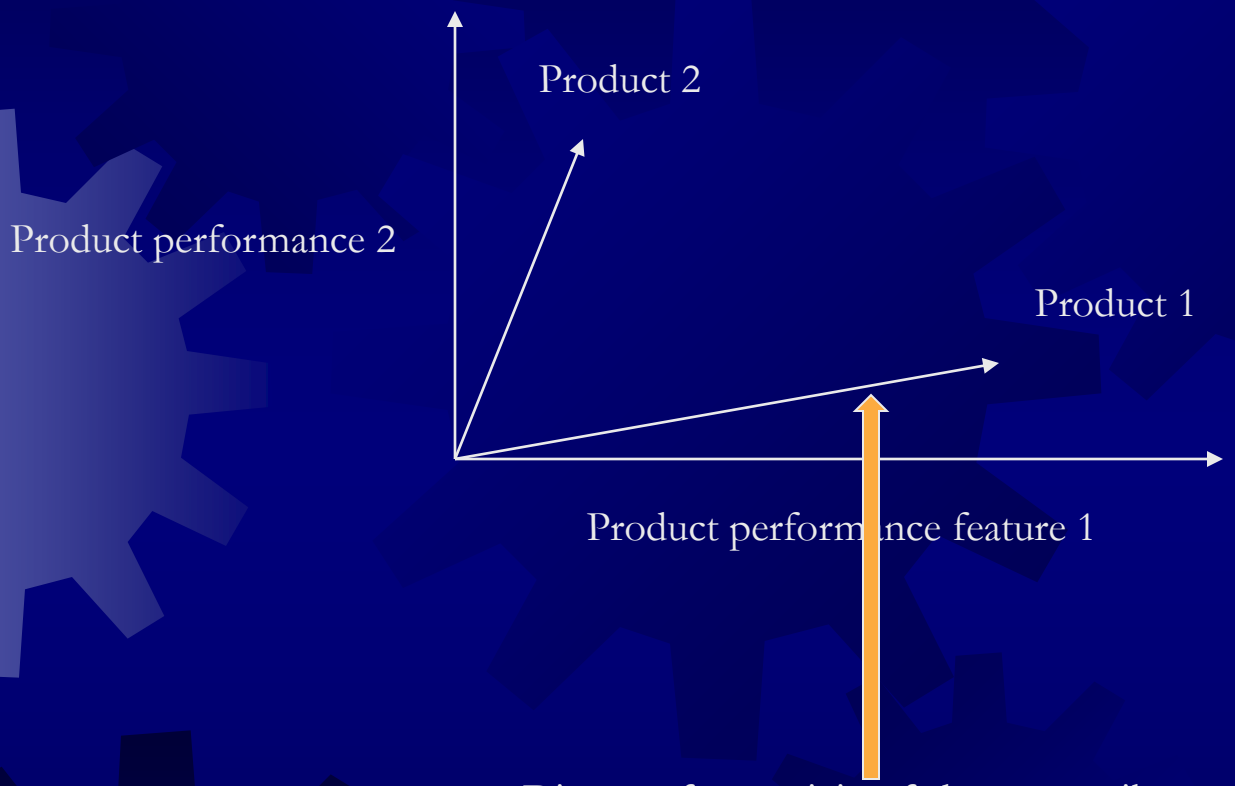
- *DV: matching the agility of the disruptive products*
- *IVs: Inhouse users (IHU) of MTs; Prior component experience*
- *Controls*

Responses of firms during disruption



Distance from origin of the most agile product manufactured by an US firm in a given year (= d1)

Responses of firms during disruption



Distance from origin of the most agile product in a given year (= d2)

Agility measure for a firm in a given year= d1/d2

Dependent Variable

- *7 size categories * 8 type categories of MTs*
  - Sizes of MTs:
    - <5 HP
    - 5 <HP <= 10
    - 10 < HP <= 15
    - 15 < HP <= 25
    - 25 < HP <= 50
    - 50 < HP <= 100
    - HP > 100

Types of MTs

AMT Category	Subcategories of MTs
12	Sub-category 1: Lathes, Turning Centers, Turret Lathes
12	Sub-category 2: Bar and Chuckers
12	Sub-category 3: Vertical Turning Centers, Vertical Boring Machines
8	Sub-category 4: Horizontal Machining Centers
8	Sub-category 5: Horizontal Milling Machines
8	Sub-category 6: Horizontal Boring Machines
8	Sub-category 7: Vertical Machining Centers
8	Sub-category 8: Vertical Milling Machines

Independent Variables

- *Pre-existing component capability:* maximum number of different components that a firm used from 1975 to 1980
  - Maximum possible breadth: 31

Components and subsystems used in manufacturing MTs

	Engine Lathe	Turret Lathe	NC Machining and Turning Centers	CNC Machg and Turning Centers	Small CNC Machg and Turning Ctrs
Gear	x	x			
Bearings	x	x	x	x	x
Spindle	x	x	x	x	x
Spring		x			
Hydraulic System		x		x	x
Capacitator				x	x
Pressure sensor				x	x
Torsional rigidity					x
Thermal stability					x

Components, subsystems, and performance of MTs

Components and Subsystems	Function	Performances affected
Recirculating ballscrew	Slideway motion	Rapid ipm; number of axes
Bearings	Friction reduction	Spindle rpm, rapid ipm, number of axes
Hydraulic subsystems	Tool release	Number of axes; number of spindles
Thermal stability subsystems	Thermal drift reduction	Spindle rpm, rapid ipm, number of spindles
Torsional rigidity subsystems	Flexure reduction	Spindle rpm, number of axes

Methods

- Estimates of the coefficients of the hedonic regressions (pre-disruption and disruption periods):
  - Effect of spindle rotation (RPM), rapid traverse (IPM), no. of axes, and no. of spindles on the price of the product
  - Horse power and market share as controls
  - Panel regression with year fixed effects
- Estimates of Performance response:
  - Feasible generalized 2SLS
  - PCSE
  - FLOGIT

Estimates of coefficients (N=264)

	Model 1: Control variables		Model 2: Hypotheses	
Component Experience			0.0016	***
			(0.0004)	
IHU			0.0094	***
			(0.0025)	
Age	-0.0032		-0.0015	
	(0.0022)		(0.0019)	
Sales	0.0006		0.0001	
	(0.0009)		(0.0009)	
Year dummy		***		***
Patent 1970-1980	1.89E-06		-0.0001	
	(0.0001)		(0.0001)	
Product count	-0.0008	**	-0.0011	***
	(0.0003)		(0.0003)	
Proportion	-0.0080		0.0007	
	(0.0053)		(0.0048)	
CNC ratio	0.0074	***	0.0045	†
	(0.0023)		(0.0024)	
Constant	1.0017	***	0.9914	***
	(0.0104)		(0.0093)	
Wald Chi Sq	56.96		80.58	

† p<0.1; * p<0.05; ** p<0.01; *** p<0.001

Take-aways

- Christensen-type disruption is not necessarily a "dilemma"
- American MC MT manufacturers with certain capabilities did respond to the disruptive CNC threat
- Capabilities that are critical for disruption
  - Access to inhouse users
  - Prior experience
- Don't be scared just because you face the threat of disruption!

Extensions of this study

- Industrial robotics
- Vision sensors
  - CCD and CMOS

Thank you!

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