Product Innovation, Product Diversification, and Firm Growth: Evidence from Japan's Early Industrialization

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Firm Growth and Product Line Expansion

Lots of evidence that firms usually grow by adding product varieties

- Most empirical work looks at manufacturers
- But some for services too (e.g., Hsieh and Rossi-Hansberg's "Industrial Revolution in Services"—geographic expansion is one type of variety)
- Famous anecdotes: Google Alphabetizes, Amazon expands

Firm Growth and Product Line Expansion

All frameworks assume a certain degree of symmetry among products

- In expectation, all potential product introductions are equally effective channels for growth

But supply- and demand-side effects may be different

- Consumers' willingness to substitute and firms' economies of scope are driven by very different primitives

Innovative products may create spillovers that me-too products do not

Bottom line: It might not just be the number, but type, of products that matter for growth

Firm Growth and Product Line Expansion

We have the data to treat products as different, and we find those distinctions matter

Our setting: Japanese cotton spinning industry 1893-1914

We find:

- Vertical and horizontal product expansions are different
    - Vertical: climbing up the technological ladder
    - Horizontal: making new varieties within firm’s existing technology
- Vertical expansions are necessary ingredient in long-run firm growth
    - Vertical expansions necessary for *horizontal* product growth
- Horizontal expansions don’t make vertical expansions easier
- Attempts at vertical expansions often fail and are retried
- Mechanisms related to greater flexibility and demand-side “appeal”

Similar Cases/External Validity

- Our findings may not apply universally, but are empirically observed in a range of other contexts
  - Industry level
    - Global mobile phone industry: leaders jumped into high-end phones first, then captured the low-end market (even before smartphones!)
    - Robotics: strong impact of interaction between what they call “new knowledge” and “adding depth to existing knowledge” on the diversity of the product portfolio
  - Firm level
    - Honda: used race cars as a springboard for consumer car market
    - Shimano: brand appeal of high-end drivetrains translated into success in the low-end market
    - TSMC: production flexibility by reusing obsolete high-end capacity

Conceptual Framework

(Not trying to break new theoretical ground; borrows heavily from McCardle (1985) and Jovanovic (1982); just making sense of our findings)

- Firms endowed with growth potential but know only the prior distribution
- Can run costly product upgrade trials to learn more
- Entering trials involves a fixed cost (new machines, engineers, etc.)
  - Only select firms enter trials (selection treated separately)
- Conditional on entering trials, these succeed or fail
  - Successful trials boost growth and knowledge/brand appeal
  - Knowledge/brand appeal useful across the spectrum
- Too many unsuccessful trials $\Rightarrow$ exit trials, join firms that never tried
- Enough successful trials $\Rightarrow$ exit trials and grow through portfolio diversification (apply accumulated knowledge/brand appeal to low-end products)

Conceptual Framework: Empirical Implications

- *Sorting pattern—three firm types in the long run*:
  1. No product upgrading (empirically, about half of the sample)
  2. Mostly failed product upgrade trials (introduced high-end machines but failed to diversify, eventually acquired by type-3 firms)
  3. More successful product upgrade trials, moved to product diversification (became fast-growing firms, serial acquirers)
- *Product varieties and firm growth*
  - Past upgrade trials predict growth only marginally (mix of type-2 and type-3 firms)
  - Subsequent product diversification isolates high-growth firms $\Rightarrow$ strong positive growth effect of the interaction term
- *Output cuts as a source of exogenous variation*
  - Coincidence of industry-wide mandatory output cuts on low-end products and the arrival of high-end machine orders reduced opportunity costs of upgrade trials
    - Neither can be timed, so pretty much an exogenous cost-shifter

Setting and Data

Japan's cotton spinning industry was the first modern manufacturing industry in Asia; at world frontier by 1915-20

Supply chain:
Raw Cotton → Cotton Spinning → Textile Weaving → Textile products

Output is "yarn" (read: thread)

Two important attributes: count (fineness) and finish

- Count: units of yarn length that have a given weight
    - Higher counts mean finer (higher quality) yarn
- Finish: the way threads are spun
    - Right-twist and left-twist are standard and treatable as equivalent
    - Doubled and gassed yarns are higher quality

Setting and Data

Monthly plant-level data

- Production in physical units of yarn by type (count-by-finish)
  - We consolidate 201 types in raw data to 35 types
  - We sometimes dichotomize yarn into “low-end” and “high-end”; high-end is above 20-count and/or doubled or gassed
- Input use (operating spindles, workers, raw cotton) in physical units
- Output prices (for select counts)
- Wages
- Existence of industry-mandated output restrictions

Semiannual plant-level data

- Machine installed capacity, orders, and installations
- Number of engineers
- Composition of firm’s board of directors

Setting and Data

明治参拾九年拾貳月中全國紡績會社製糸

Statement showing umber of Bales (About 400 lbs) of YARN Produced in the Cotton Mills in

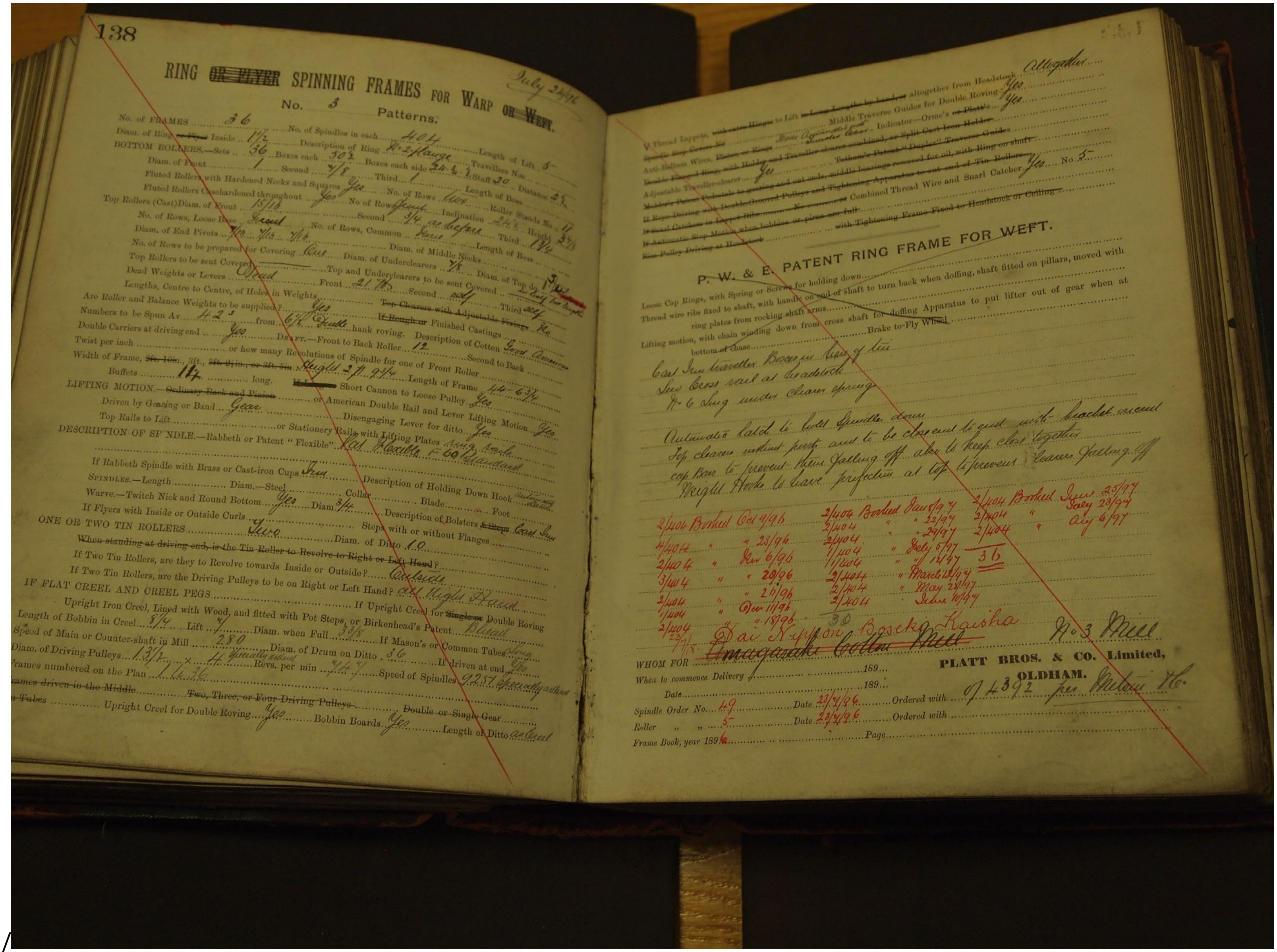
右撚 Weft.

會社名 Names of Mills	10以下	10	11	12	13	14	15	16	17	18	19	20	22	24	30
大阪 Osaka	243.0	—	—	448.0	302.0	2,211.0	154.0	1,206.0	143.0	—	3.0	—	—	—	—
攝津 Settsu	—	649.0	—	508.5	294.5	519.0	149.5	5,385.5	—	—	—	—	—	—	—
大阪合同 Osaka Godo	—	366.0	101.0	319.0	177.0	301.5	165.5	1,216.0	—	—	—	—	—	—	—
福島 Fukushima	—	—	—	—	—	—	—	2,419.0	—	—	—	—	—	—	—
日本紡績 Nihon	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
天滿織物 Tenma W.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
内外紡織 Naigai S. W.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
仝 第二工場	—	—	—	—	—	—	—	142.0	—	—	—	—	—	—	—
小津細糸 Ozu Hosoito	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
久保吉 Kuboyoshi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
堺 Sakai	—	—	—	—	—	—	—	747.5	—	—	—	—	—	—	—
岸和田 Kishiwada	—	—	—	—	—	—	—	209.0	—	—	—	—	—	—	—
和歌山 Wakayama	—	—	—	—	—	311.5	—	—	—	—	—	—	—	—	—
和歌山織布 Wakayama	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
郡山 Kōriyama	—	32.5	—	—	—	—	—	130.5	—	117.5	—	—	—	—	—
京都綿ネル Kyoto	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
八幡 Yawata	—	154.0	—	—	—	—	—	—	—	—	—	—	—	—	—
村井紡績	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
尼崎 Amagasaki	225.5	467.0	—	235.0	—	—	—	—	—	—	—	—	—	—	—
播磨 Harima	—	—	—	—	—	—	—	720.0	—	—	—	—	—	—	—
飾磨	—	184.0	—	85.5	—	—	—	—	—	—	—	—	—	—	—
岡山 Okayama	—	—	—	—	—	42·5	47·5	1,986.5	—	—	—	—	—	—	—
倉敷 Kurashiki	—	—	—	—	—	20.0	84.0	1,590.0	—	—	—	—	—	—	—
笠岡 Kasaoka	—	—	—	—	—	—	—	822.0	—	—	—	—	—	—	—
備前 Bizen	—	—	—	—	—	.5	—	1,024.0	.5	—	—	—	—	—	—
下村 Shimomura	—	—	—	—	—	100.0	—	271.0	—	—	—	—	—	—	—
江商紡績	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
吉備 Kibi	—	252.0	—	141.0	109.0	299.5	99.0	780.0	—	—	—	—	—	—	—
半田 Handa	—	—	—	—	—	—	—	327.0	—	—	—	—	—	—	—
貝塚 Kaizuka	—	72.0	—	—	—	—	—	—	—	—	—	—	—	—	—
松山 Matsuyama	—	—	—	—	—	—	—	64.0	—	157.0	—	80.5	—	—	—
伊予八幡濱 Yawatahama	—	53.0	—	209.0	—	—	—	—	—	—	—	—	—	—	—
白石 Shiraishi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
讃岐 Sanuki	—	—	—	—	—	422.0	—	450.0	—	—	—	—	—	—	—
阿波 Awa	—	—	—	—	—	13.0	—	395.0	—	—	—	—	—	—	—
三重 Miye	9.0	5.0	17.0	37.0	—	272.0	295.0	2,814.0	—	384.0	—	—	—	—	—
桑名 Kuwana	—	—	—	—	—	52.5	12.0	828.0	—	—	—	42.0	—	—	—
一宮 Ichinomiya	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
知多 Chita	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
島田 Shimada	—	—	—	—	—	—	—	—	—	—	—	—	—	—	51.5
甲府 Kofu	—	—	—	113.0	—	—	—	—	—	—	—	—	—	—	—
渡邊 Watanabe	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
鐘淵 Kanegafuchi	155.5	852.5	169.0	1,083.0	689.0	959.5	353.5	6,270.0	—	276.5	—	63.0	—	—	—
富士瓦斯 Fuji Gasu	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
東京 Tokyo	—	—	—	—	—	198.5	19.0	83.0	—	—	—	—	137.0	37.0	—
下野 Shimotsuke	—	49.0	97.0	200.0	—	—	—	—	—	—	—	—	—	—	—
高岡 Takaoka	—	37.0	—	72.0	228.0	132.0	84.0	242.0	—	—	—	—	—	—	—
宮城 Miyagi	—	15.0	—	—	—	—	—	—	—	—	—	—	—	—	—
合計 otal	633.0	3,188.0	384.0	3,451.0	1,799.5	5·855·0	1,463.0	30,122.0	143.5	935.0	3.0	185.5	137.0	37·0	51.5
前月 November 1906	485.5	3,341.5	418.0	3,573.0	1,492.0	6,067.0	1,304·5	29,514.5	126.0	923.5	—	227.5	—	—	44.5
前年仝月 December 1905	485.5	3,900.0	687.0	2,974.0	1,740.0	4,728.0	1,995·5	28,491.0	49.5	940.5	—	399.0	104.0	—	54.0

左撚 Twist.

會社名 Names of Mills	10以下	10	11	12	13	14	15	16	17	18	19	20	21	22	24	26	28	30	32	34	36
大阪 Osaka	—	—	—	—	—	—	—	—	—	—	—	444.0	—	—	—	—	60.0	423.0	213.0	—	—
攝津 Settsu	—	—	—	—	—	—	—	74.5	—	—	—	1,021.5	—	—	—	—	—	—	—	—	—
大阪合同 Osaka Godo	—	—	—	—	—	—	—	—	—	—	—	1,439.0	—	—	—	—	38.5	300.5	279.5	—	—
福島 Fukushima	—	—	—	—	—	—	—	—	—	—	—	377.0	—	—	—	—	—	—	—	—	—
日本紡績 Nihon	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
天滿織物 Tenma W.	—	—	—	103.0	63.0	100.0	50.0	—	40.0	—	—	—	—	—	—	—	—	—	—	—	—
内外紡織 Naigai S. W.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
仝 第二工場	—	—	—	—	—	—	—	—	—	138.5	—	497.0	—	—	—	—	—	—	—	—	—
小津細糸 Ozu Hosoito	—	—	—	—	—	—	—	—	—	—	—	201.5	—	—	—	—	.5	—	—	—	—
久保吉 Kuboyoshi	—	—	—	—	—	—	—	—	—	—	—	95.0	—	—	—	—	—	—	—	—	—
堺 Sakai	—	—	—	—	—	—	—	—	—	—	—	360.0	—	—	—	—	—	—	—	—	—
岸和田 Kishiwada	—	—	—	—	—	—	—	—	—	—	—	1,940.0	—	—	—	—	—	—	—	—	—
和歌山 Wakayama	—	—	—	—	—	—	—	—	—	—	—	920.0	—	—	—	—	—	—	—	—	—
和歌山織布 Wakayama	184.0	63.0	—	—	—	—	—	—	—	—	—	202.0	—	—	94.0	—	—	54.0	—	—	—
郡山 Kōriyama	—	—	—	—	—	—	—	—	—	64.0	—	831.5	—	—	—	—	—	—	—	—	—
京都綿ネル Kyoto	584.0	—	—	—	—	—	—	—	—	—	—	321.5	—	—	—	—	—	—	—	—	—
八幡 Yawata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
村井紡績	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	35.5	—	54.0
尼崎 Amagasaki	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
播磨 Harima	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
飾磨	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
岡山 Okayama	—	—	—	—	90.0	476.0	—	—	—	—	—	2.0	—	—	—	—	—	—	—	—	—
倉敷 Kurashiki	—	—	—	—	—	—	—	—	—	—	—	131.0	—	—	—	—	—	—	—	—	—
笠岡 Kasaoka	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
備前 Bizen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
下村 Shimomura	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
江商紡績	—	—	—	—	—	—	—	—	—	—	—	421.0	—	—	—	—	—	—	—	—	—
吉備 Kibi	—	3.0	—	14.5	—	—	—	33.0	—	2.5	—	207.0	—	—	—	—	—	—	—	—	—
半田 Handa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
貝塚 Kaizuka	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
松山 Matsuyama	—	—	—	—	—	—	—	—	—	—	—	44.0	—	—	—	—	—	—	—	—	—
伊予八幡濱 Yawatahama	—	—	—	—	—	—	—	—	—	—	—	185.0	—	—	—	—	—	—	—	—	—
白石 Shiraishi	—	—	—	—	—	—	—	—	—	—	—	294.0	—	—	—	—	—	—	—	—	—
讃岐 Sanuki	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
阿波 Awa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
三重 Miye	—	—	—	—	—	—	—	3,107.0	—	—	—	1,990.0	—	79.0	21·0	—	—	601.0	61.0	—	—
桑名 Kuwana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	118.5	—	—	—
一宮 Ichinomiya	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	26.5	—	—	—
知多 Chita	—	—	—	—	—	—	—	—	—	—	—	995.0	—	—	—	—	—	—	—	—	—
島田 Shimada	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
甲府 Kofu	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
渡邊 Watanabe	—	—	—	—	—	—	—	—	—	—	—	89.[illegible]	—	—	—	—	—	32.0	—	—	—
鐘淵 Kanegafuchi	115.0	—	—	—	—	—	—	38.0	—	126.5	—	3,217.0	89.0	—	157.0	—	214.0	446.5	607.0	—	—
富士瓦斯 Fuji Gasu	—	—	—	—	241.5	206.0	138.0	189.0	—	—	—	375.5	—	—	—	—	—	—	176.5	—	—
東京 Tokyo	—	—	—	—	—	—	—	18.0	—	—	—	850.0	—	—	—	—	—	85.0	134.0	—	—
下野 Shimotsuke	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
高岡 Takaoka	—	—	—	—	—	—	—	—	—	—	—	25.0	—	—	—	—	—	—	—	—	—
宮城 Miyagi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
合計 otal	883.0	66.0	—	117.5	394.5	782.0	188.0	3,459.5	40.0	331.5	—	17,475.5	89.0	79.0	272.0	—	313.0	2,087.0	1,506.5	—	51.0
前月 November 1906	770.5	210.0	1.0	[illegible]	390.0	650.0	192.0	657.5	3,143.0	426.5	—	18,057.0	90.0	158.0	237.0	—	103.0	1,830.0	1,557.0	—	52.5
前年仝月 December 1905	692.5	100.0	1.5	260.0	119.0	263.0	520.5	3,457.0	96.0	368.0	105.0	20,374.0	84.5	33.0	185.0	—	205.0	1,345.0	1,352.5	—	141.5

Setting and Data



Setting and Data

Key definitions

- Product upgrade/vertical expansion is making new yarn type that is:
  - High-end AND
  - Has higher count than any the firm previously made "at scale"
    - At scale: accounting for at least 3% of firm's output
- Product diversification: making a new yarn at scale at a count lower than or equal to any count the firm previously made
- Product trials: making a yarn in period t that a) the firm did not make in $t-1$ (semiannual periods), b) is not made at scale in t, and c) had never been made at scale by the firm before t
  - Trials can succeed—grow to reach production at scale
  - Trials can fail but be retried later

Trials

Firm-by-product-line production episodes

	All (1)	Fraction of total	Never scaled (2)	Ratio (2)/(1)
New product lines	685	1.000	271	0.396
Of which: never a trial	246	0.359		
initially trial products	439	0.641	271	0.617
Of which: Upgrade lines	76	0.111	33	0.434

Experiments

	All	Successful (scaled)	Failed (not scaled)	Fraction failed
All trial products	819	223	596	0.728
Of which: upgrades	116	42	74	0.638
diversifications	703	181	522	0.743
fraction upgrades	0.142	0.188	0.124	

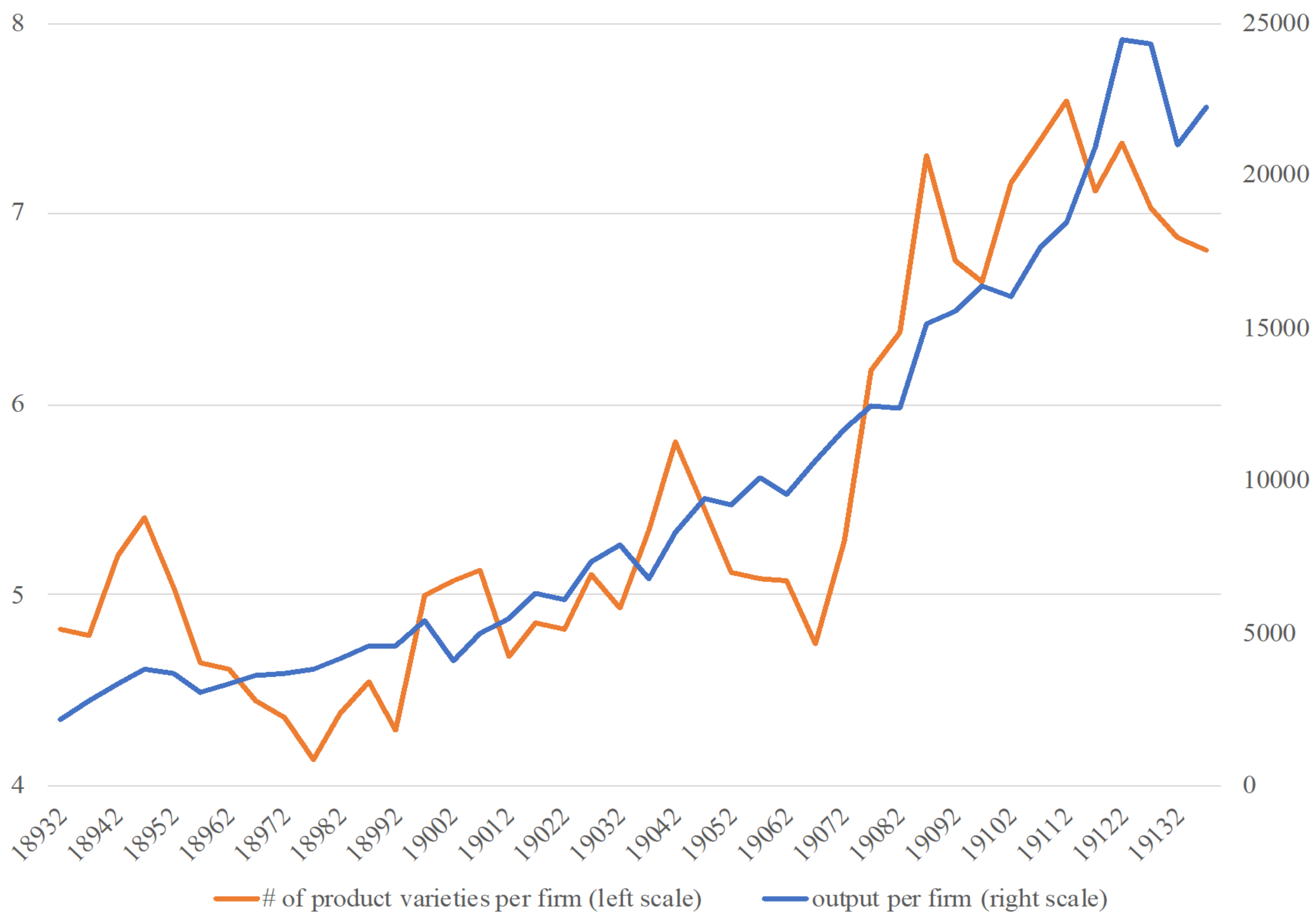
Trials

Trials usually fail, two-thirds to three-fourths of the time

Given that trials are small by definition and often fail, they themselves cannot be a source of growth

However, we will show that trials are related, probably causally, to firm growth through product expansion

Firm Growth and Product Expansion

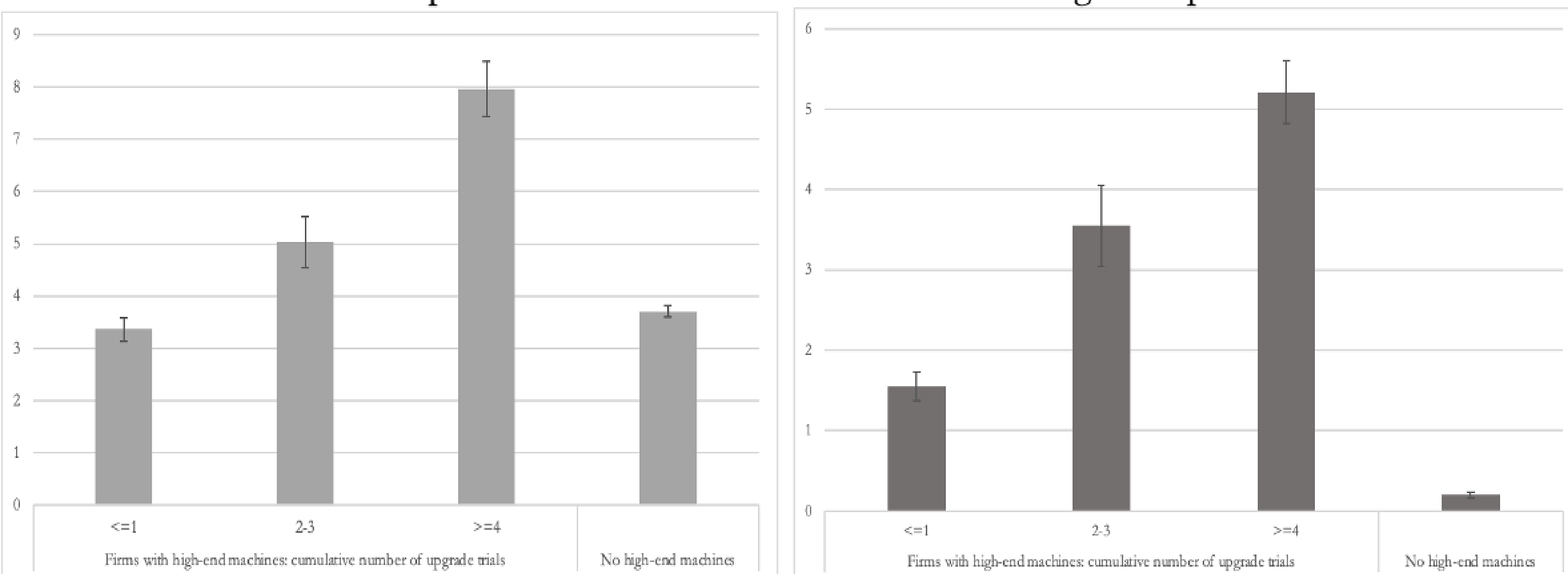


Upgrade Trials and Product Expansion

Figure 2.

Panel A. Cumulative upgrade trials and number of low-end and high-end products in firms' portfolios

Low-end products High-end products

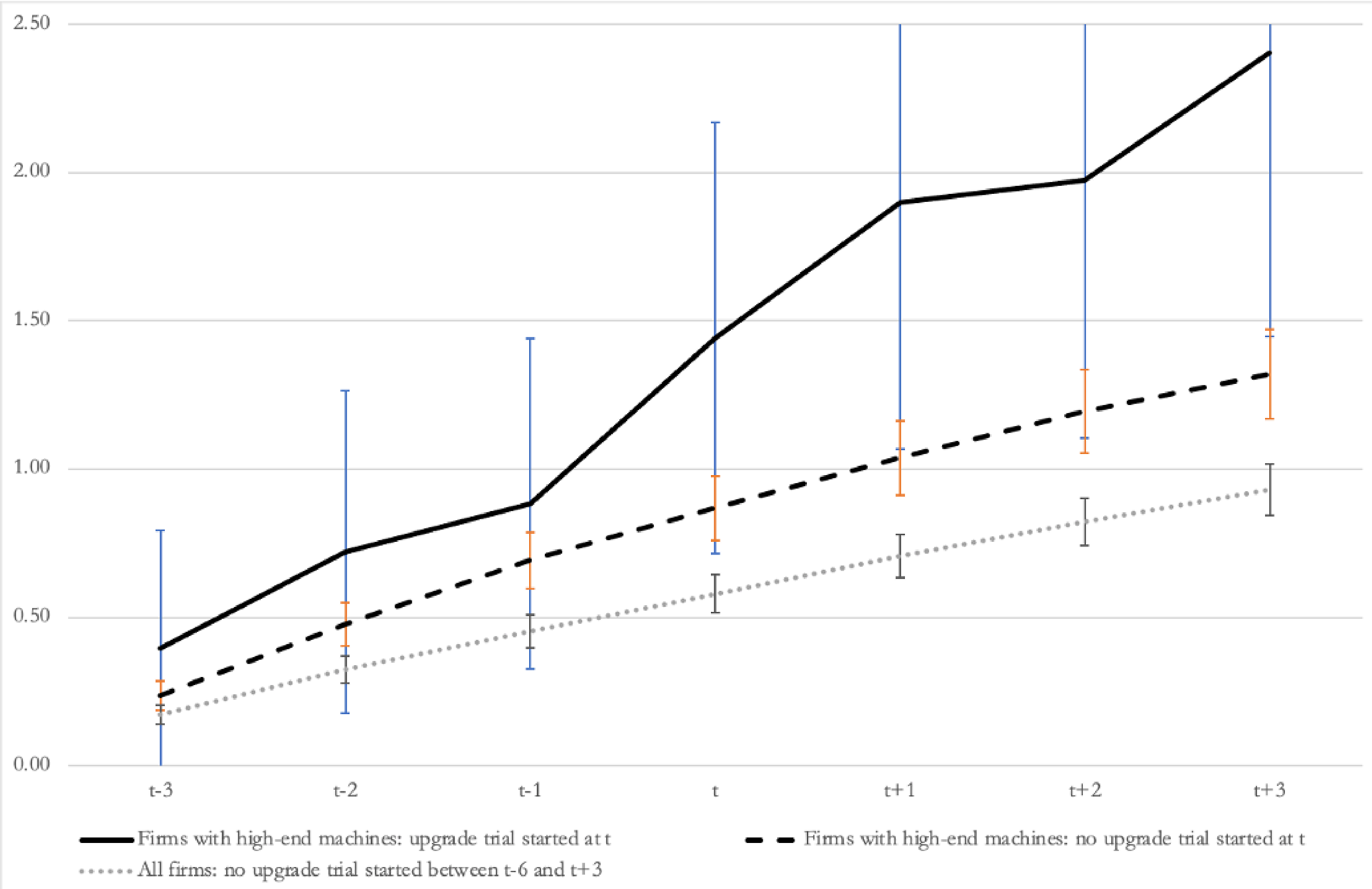


From regression analysis: Cumulative upgrade trials 25th %ile = 1, 75th %ile = 5

IQR tied to about 1.7 (0.43x4) additional new varieties

Upgrade Trials and Product Expansion (cont.)

Figure 2.
Panel B. Dynamics of cumulative new-to-firm horizontally diversified products from *t*-3 to *t*+3 after a product upgrade trial at *t* (if any)



What Drives Product Upgrade Trials?

Number of UPGRADE experiments in *t*:

		All Firms		Firms with high-end machines	
I[had high-end machine in *t*]	1.066***				
	(0.378)				
I[installed high-end machinery in *t*]		1.387***	0.700**	0.943***	0.295
		(0.305)	(0.379)	(0.343)	(0.362)
I[installed high-end machinery in *t*] x I[mandated output cuts in effect in *t*]			1.111*		1.846***
			(0.588)		(0.603)
I[installed low-end machinery in *t*]		-0.002	-0.132	-0.039	-0.045
		(0.334)	(0.374)	(0.420)	(0.431)
I[employs univ.-educated engineer in *t*]			0.565		0.485
			(0.421)		(0.494)
I[has exchange merchant on board in *t*]			1.455***		1.666***
			(0.416)		(0.547)
Controls: period FEs, "age" dummies	Yes	Yes	Yes	Yes	Yes
N	1,618	1,618	1,618	701	701

What Drives Product Upgrade Trials?

Number of DIVERSIFICATION experiments in *t*:

	All Firms			Firms with high-end machines	
I[had high-end machine in *t*]	0.941***				
	(0.209)				
I[installed high-end machinery in *t*]		1.099***	0.830***	0.746***	0.582*
		(0.210)	(0.300)	(0.212)	(0.297)
I[installed high-end machinery in *t*] x I[mandated output cuts in effect in *t*]			0.059		0.288
			(0.423)		(0.424)
I[installed low-end machinery in *t*]		0.236	0.148	0.138	0.072
		(0.215)	(0.218)	(0.260)	(0.257)
I[employs univ.-educated engineer in *t*]			0.743***		0.675***
			(0.177)		(0.211)
I[has exchange merchant on board in *t*]			0.387**		0.442*
			(0.163)		(0.268)
Controls: period FEs, “age” dummies	Yes	Yes	Yes	Yes	Yes
N	1,618	1,618	1,618	701	701

High-End Machines

	Firms with high-end machines	Firms without high-end machines
Fraction of firms with merchant board member	0.71	0.57
Number of university-educated engineers	1.61	0.14
Number of technical-college-educated engineers	4.76	0.72
Experimental product introductions per period: All	0.60	0.25
Of which, fraction successful	22%	34%
Experimental product introductions: Upgrade	0.10	0.03
Of which, fraction successful	32%	36%
Experimental product introductions: Diversification	0.50	0.22
Of which, fraction successful	18%	35%
Non-experimental product introductions: All	0.11	0.11
Non-experimental product introductions: Upgrade	0.06	0.01
Non-experimental product introductions: Diversification	0.05	0.09

What Drives Product Upgrade Trials? An IV

An IV for upgrade trials: interact a) installing high-end machinery in *t* and b) imposition and magnitude of mandated output cuts in *t*

- Relevance condition
  - High-end machinery correlated with making high-end products; output cuts imposed on low-end product types free up firm resources to try new things
- Exclusion condition
  - Delivery time lags of high-end machine orders are 1-2 years (sometimes longer) and uncertain
    - Unlikely firm can anticipate imposition or size of mandated output cuts that far in the future
  - Mandated cuts from aggregate demand fluctuations unlikely to be tied to shifts in firms' unobservable innovative capabilities

Product Upgrade Trials and Growth

	DV: number of upgrade experiments started at *t*		DV: Δln(output)	
	First stage	Placebo test	Second stage	
Cumulative upgrade experiments			0.012	-0.014
			(0.012)	(0.014)
Fraction of products that are low-end	-2.371***	-2.360***	-0.029	-0.080**
	(0.463)	(0.461)	(0.027)	(0.039)
(Cumulative upgrade experiments) x fraction low-end products				0.081**
				(0.034)
(Fraction output subject to cuts) x Δln(installed high-end spindles)	2.539***			
	(0.647)			
(Fraction output subject to cuts) x Δln(installed low-end spindles)		-0.040		
		(0.565)		
Controls: Δln(installed spindles), engineer and merchant board member dummies, logged output, period FEs, "age" dummies	Yes	Yes	Yes	Yes
N	1,608	1,608	1,608	1,608
Estimation	Poisson	Poisson	IV	IV

Additional upgrade experiment for firm at mean fraction of low-end products raises growth rate by about 5.5% (one-third of IQR)

Growth Mechanisms: Production Flexibility

Measure in monthly data how often a firm rebalances its product portfolio

Changes in “lead direction” of twists within counts

- E.g., firm had been producing 80% left-twist and 20% right-twist 16-count and then in next month shifts to 30% left-twist and 70% right-twist

Changes in “lead count” within finishes

- E.g., firm had been producing 80% 16-count and 20% 20-count and then in next month shifts to 30% 16-count and 70% 20-count

We focus on these changes for low-end products

Growth Mechanisms: Production Flexibility

	Number of changes in lead direction	Number of changes in lead count	Δln(output)	Δln(output)
Cumulative upgrade experiments	0.241***	0.153*		
	(0.083)	(0.085)		
Cumulative diversification experiments	0.022	0.012		
	(0.016)	(0.024)		
Number of changes in lead direction			0.010**	
			(0.004)	
Number of changes in lead count				0.012***
				(0.004)
I[employs univ.-educated engineer in *t*]	0.190	-0.091	0.103**	0.103**
	(0.152)	(0.293)	(0.041)	(0.041)
I[has exchange merchant on board in *t*]	0.084	0.154	0.011	0.008
	(0.098)	(0.170)	(0.026)	(0.025)
I[installed high-end machinery in *t*]	0.184	0.258**	0.014*	0.014*
	(0.141)	(0.122)	(0.007)	(0.007)
I[installed low-end machinery in *t*]	0.171	-0.003	-0.002	-0.002
	(0.127)	(0.111)	(0.015)	(0.015)
Total output	-0.033	-0.138***	-0.298***	-0.296***
	(0.035)	(0.038)	(0.048)	(0.047)
N	1,605	1,605	1,608	1,608
Period and firm FEs	Yes	Yes	Yes	Yes

Add’l upgrade experiment tied to increase in lead direction (count) of half (one-eighth) its mean

Growth Mechanisms: Demand Appeal

Measure quality of *low-end* products

Quality metric: Khandalwal (2010)-style demand estimation

- Essentially, product's market share after controlling for price differences

We don't have price data for every product, but we do for a key 20-count yarn that accounted for around ¼ of industry output

IV for price: lead-count changes production flexibility measure from above, interacted with output controls (imposed on yarns up to 20-count)

- Intuition: flexible firms could more easily substitute to counts above 20 when output controls were in place, and as such did not need to reduce 20-count prices as much
- But not lead-twist—shouldn't have effect on pricing

Growth Mechanisms: Demand Appeal

Demand Estimation

	DV: ln(20-count price)		DV: ln(share)
	First stage	Placebo test	Second stage
ln(20-count price)			-5.407
			(6.136)
Lead-count changes	-0.002**		
	(0.001)		
(Lead-count changes) x (mandated output cuts)	0.032***		
	(0.007)		
Lead-twist changes		-0.001	
		(0.001)	
(Lead-twist changes) x (mandated output cuts)		0.005	
		(0.006)	
Controls: Period and firm FEs	Yes	Yes	Yes
N	743	743	743

Growth Mechanisms: Demand Appeal

	DV: Quality			
	OLS	OLS	IV	IV
Cumulative upgrade experiments	0.067***	-0.037	0.503***	-0.101
	(0.026)	(0.081)	(0.062)	(0.217)
(Cumulative upgrade experiments) x (fraction of low-end products)		0.158		0.925***
		(0.114)		(0.320)
Fraction of low-end products	0.884***	0.803***	1.532***	1.028***
	(0.289)	(0.294)	(0.289)	(0.364)
I[employs univ.-educated engineer in *t*]	0.989***	1.001***	0.763***	0.762***
	(0.118)	(0.119)	(0.116)	(0.117)
I[has exchange merchant on board in *t*]	0.189*	0.167	0.027	-0.056
	(0.112)	(0.112)	(0.107)	(0.110)
Controls: Δln(installed spindles), period FEs, “age” dummies	Yes	Yes	Yes	Yes
N	721	721	721	721

Robustness: Mean Growth or Variance of Growth?

Firms that make high-end products are more likely to survive to the end of the sample

	Survivors	Exit (acquired)	Exit (liquidated)	Total
Had high-end machines	19	22	1	42
No high-end machines	14	31	18	63
Total	33	53	19	105

Conclusions and Discussion

Product expansion and firm growth go together in our sample, as the literature has found in other settings

However, all product-line expansions are not the same

Clear asymmetry in product expansion and growth patterns in our sample

High-growth firms went outside their existing technological frontiers and experimentally introduced innovative products

- This led to growth not just in high-end products, but low-end as well
- Low-end/diversification experiments are not related to long-run growth
- Mechanism behind high-end-driven growth seemingly related to knowledge gains in manufacturing flexibility and improvements in some notion of demand-side appeal