Firm Technology Upgrading Through Emerging Work

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[1]Research results and conclusions expressed are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of Philadelphia, the Federal Reserve System, or the Federal Reserve Board of Governors.

Background

- Key question in economic growth: Which firms adopt new technologies?
  - Important for understanding firm-level productivity, industry dynamics, aggregate growth.
  - Difficult to construct comprehensive and comparable firm-level measures
- Our hypothesis: Firms' job ads not only lead to employer-employee matches, but also signal their adoption of new technologies

This paper: How do hiring decisions reflect new technology adoption?

- Explore firms' job vintages, in their vacancy postings, over 1940-2000.
  - 5 million ads from the *New York Times*, *Boston Globe*, and *Wall Street Journal*
  - Vintage: When in the sample did each job title tend to appear
  - For example: "Comptometer Operator" tended to appear earlier on than "Figure Clerk", likely represents older technology.
- Job title vintages provide a new measure of firms' technology adoption

This paper: How do hiring decisions reflect new technology adoption?

- There is substantial heterogeneity in the mix of job title vintages across firms.
- Among publicly traded firms, newer job vintages correlated with R&D intensity, future sales growth.
- Among all firms, those posting for newer job vintages entered more recently, are more likely to survive, have more patents
- For which types of occupations is having newer vintage jobs most important?
- Having newer vintage jobs in organizational (management, financial, sales, and administrative) occupations seems particularly critical for R&D expenditures and being publicly traded
- Vintages in other occupations are more closely related to sales growth.

Contribution

Measurement of innovation, technology adoption, or new work

- ... looks at adoption incentives within individual firms or industries (Griliches 1957, Henderson 1995, Arora and Gambardella 1994)
- ... looks at aggregate technology adoption rates (Comin, Hobijn, and Rovito, 2008, Comin and Hobijn, 2010)
- ... or focuses on new work (Lin, 2011; Autor, Salomons, Seegmiller, 2024; Kim, Merritt, Peri, 2025).

Our contribution: Present measurement of firm technology adoption across multiple industries, over a long time period

Outline

1. Data set and job vintage measures
2. Job title vintage is an indicator of innovative, high-skilled activity.
3. Job title is predictive of future firm performance
4. Synergies and heterogeneity across groups of occupations

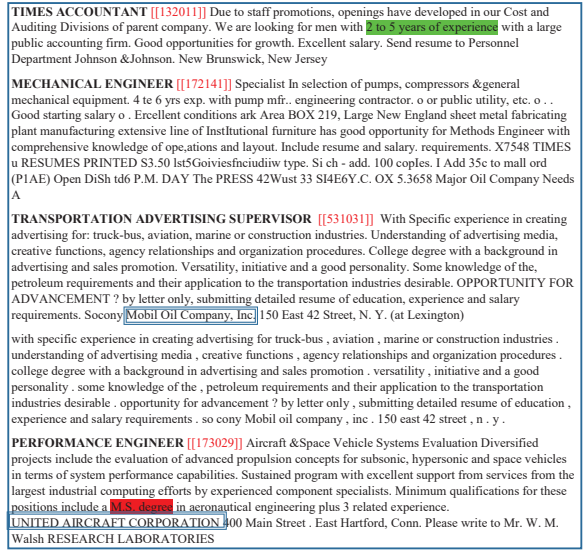
Unprocessed page of ads from the 1960 New York Times

SENIOR Leading Mid-Manhattan engineering company seeks Senior Buyer with minimum 3 purchasing experience in research and development field handling electronic corn . Capable of rea in blueprints SALARY TO $7,000 Send Complete Resume to. KK 105 TIMES ACCOUNTANTS Due to staff promotions, openings have developed in our Cost and Auditing Divisions of parent company. We are looking for men with 2 to 5 years of experience with a large public accounting firm. Good opportunities for growth. Excellent salary. Send resume to Personnel Department Johnson &Johnson. New Brunswick, New Jersey MECHANICAL ENGINEER Specialist In selection of pumps, compressors &general mechanical equipment. 4 te 6 yrs exp. with pump mfr.. engineering contractor. o or public utility, etc. o . . Good starting salary o . Ercellent conditions ark Area BOX 219, Large New England sheet metal fabricating plant manufacturing extensive line of InstItutional furniture has good opportunity for Methods Engineer with comprehensive knowledge of ope,ations and layout. Include resume and salary. requirements. X7548 TIMES u RESUMES PRINTED S3.50 lst5Goiviesfnciudiiw type. Si ch - add. 100 copIes. I Add 35c to mall ord (P1AE) Open DiSh td6 P.M. DAY The PRESS 42Wust 33 SI4E6Y.C. OX 5.3658 Major Oil Company Needs A TRANSPORTATION ADVERTISING SUPERVISOR With Specific experience in creating advertising for: truck-bus, aviation, marine or construction industries. Understanding of advertising media, creative functions, agency relationships and organization procedures. College degree with a background in advertising and sales promotion. Versatility, initiative and a good personality. Some knowledge of the, petroleum requirements and their application to the transportation industries desirable. OPPORTUNITY FOR ADVANCEMENT ? by letter only, submitting detailed resume of education, experience and salary requirements. Socony Mobil Oil Company, Inc. 150 East 42 Street, N. Y. (at Lexington) PERFORMANCE ENGINEERS Aircraft &Space Vehicle Systems Evaluation Diversified projects include the evaluation of advanced propulsion concepts for subsonic, hypersonic and space vehicles in terms of system performance capabilities. Sustained program with excellent support from services from the largest industrial computing efforts by experienced component specialists. Minimum qualifications for these positions include a M.S. degree in aeronautical engineering plus 3 related experience. UNITED AIRCRAFT CORPORATION 400 Main Street . East Hartford, Conn. Please write to Mr. W. M. Walsh RESEARCH LABORATORIES

Data Set

- In past work (Atalay, Phongtheingtham, Sotelo, Tannenbaum, 2020) we processed ads from the *New York Times*, *Boston Globe*, and *Wall Street Journal*
  - For each ad we identify the job title, educational requirements, sets of tasks workers perform, technologies they use.
- New, relative to earlier work, we identify the firm name and posted salary.
- For publicly-traded firms, we link firm names to Compustat
- For all firms we hand collect entry and exit dates.
- Link firm names to patent grantees.

Processed page of ads from the 1960 New York Times



TIMES ACCOUNTANT [[132011]] Due to staff promotions, openings have developed in our Cost and Auditing Divisions of parent company. We are looking for men with 2 to 5 years of experience with a large public accounting firm. Good opportunities for growth. Excellent salary. Send resume to Personnel Department Johnson &Johnson. New Brunswick, New Jersey

MECHANICAL ENGINEER [[172141]] Specialist In selection of pumps, compressors &general mechanical equipment. 4 te 6 yrs exp. with pump mfr.. engineering contractor. o or public utility, etc. o . . Good starting salary o . Ercellent conditions ark Area BOX 219, Large New England sheet metal fabricating plant manufacturing extensive line of InstItutional furniture has good opportunity for Methods Engineer with comprehensive knowledge of ope,ations and layout. Include resume and salary. requirements. X7548 TIMES u RESUMES PRINTED S3.50 lst5Goiviesfnciudiiw type. Si ch - add. 100 copIes. I Add 35c to mall ord (P1AE) Open DiSh td6 P.M. DAY The PRESS 42Wust 33 SI4E6Y.C. OX 5.3658 Major Oil Company Needs A

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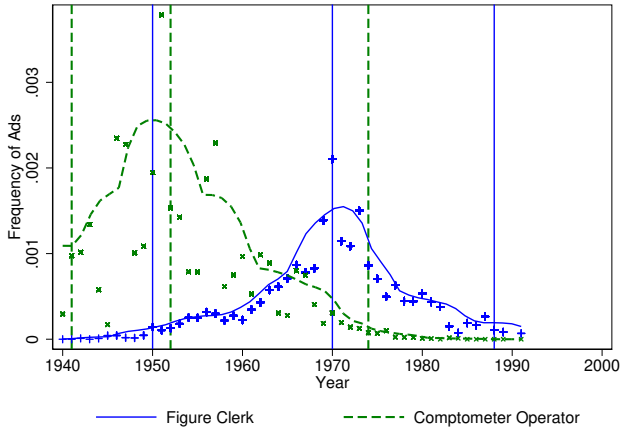
Defining Job Title Vintages



- Year of Emergence$_j$: 1st percentile of years in which j appeared
- Year of Disappearance$_j$: 99th percentile of years in which j appeared

Summary Statistics

- 5.2 million job ads for which we can identify the job title
  - 9 thousand unique job titles
  - 190 thousand ads for which we identify the posted salary
  - 252 thousand ads for which we identify the posting firm
    - Among these, 82 thousand ads correspond firms that are publicly traded

- How much dispersion is job title vintages?
  - For each year of ads, we compute average job title vintage. Relative to this average
  - Std. Dev.(Yr. of Emergence$_j$)$\approx$ 6.7 years;
  - Std. Dev.(Yr. of Disappearance$_j$)$\approx$ 6.5 years

Emerging Job Titles

Yr.	of Emergence$_j$ $\in$1950-1959	Yr.	of Emergence$_j$ $\in$1960-1969
1	administrative assistant	1	programmer analyst
2	programmer	2	computer operator
3	legal secretary	3	marketing manager
4	management trainee	4	product manager
Yr.	of Emergence$_j$ $\in$1970-1979	Yr.	of Emergence$_j$ $\in$1980-1989
1	paralegal	1	telemarketer
2	typesetter	2	hiv aid
3	word processing	3	line cook
4	word processor	4	broker trainee
Yr.	of Emergence$_j$ $\in$1990-2000		
1	power builder		
2	client server		
3	web developer		
4	web master		

Disappearing Job Titles

Yr. of Disappearance$_j$ $\in$1940-49	
1	lens grinder
2	radio instructor
3	christmas card salesperson
4	fluorescent salesperson

Yr. of Disappearance$_j$ $\in$1950-1959	
1	soda dispenser
2	millinery designer
3	buyer wants contd
4	long distance telephone operator

Yr. of Disappearance$_j$ $\in$1960-1969	
1	house worker
2	bookkeeper stenographer
3	dental mechanic
4	alteration hand

Yr. of Disappearance$_j$ $\in$1970-1979	
1	stenographer
2	stenographer typist
3	secretary stenographer
4	office boy

Yr. of Disappearance$_j$ $\in$1980-1989	
1	clerk typist
2	draftsman
3	statistical typist
4	biller typist

Comparison to Lin (2011)'s measure of new work

- Lin (2011) compares successive vintages of the Dictionary of Occupational Titles.
  $\Rightarrow$Four categories of job titles based on when they appeared ($\leq$1965, by 1977, by 1991, by 2000)
- For these four categories, plot the density of Yr. of Emergence$_j$

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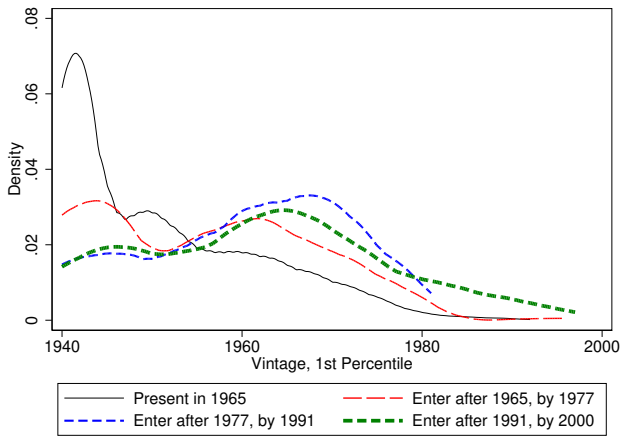

Outline

1. Data set and job vintage measures
2. **Job title vintage is an indicator of innovative, high-skilled activity.**
3. Job title vintage is predictive of future firm performance
4. Synergies and heterogeneity across groups of occupations

Relating job vintages and other ad characteristics

$$y_{at} = \beta_t + \beta_o + \beta_1 \cdot v_{j(a)}^{0.01} + \beta_2 \cdot v_{j(a)}^{0.99} + \epsilon_a \quad (1)$$

- y_a: Characteristics of ad a:
  - posted salary
  - mentions of an undergraduate or graduate degree requirement
  - mentions of an ICT (EDP, Unix, Lotus 123, FORTRAN, 44 others)
- $v_{j(a)}^{0.01}$, $v_{j(a)}^{0.99}$: Year of Emergence and Disappearance of the job title.
- β_t, β_o: year and occupation fixed effects

Newer work is associated with human capital and technology usage

Dep. Variable	Log Salary	Undergrad Degree	Graduate Degree	Technology
Year of Emergence $_j$	0.0015	0.0063	-0.0077	0.040
	(0.0002)	(0.0003)	(0.0005)	(0.001)
Year of Disappearance$_j$	0.0004	0.0033	0.0100	0.049
	(0.0002)	(0.0003)	(0.0004)	(0.001)
Sample	——	1940-2000	——	1970-2000

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	(0.0002)	(0.0003)	(0.0004)	(0.001)
Sample	——	1940-2000	——	1970-2000

A decade increase in job vintage is associated with... :

- a 1.9 log point ($\approx (0.0015 + 0.0004) \cdot 10$) increase in salaries;
- a 0.02 standard deviation increase in the frequency of undergraduate degree mentions;
- a 0.11 standard deviation increase in the frequency of technology mentions.

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Job Vintage and Firm Characteristics

Compute the average job vintage of the ads that firm i places in year t:

$$\text{Year of Emergence}_{it} = \frac{1}{|A_{it}|} \times \sum_{a \in A_{it}} \text{Year of Emergence}_j$$

$$\text{Year of Disappearance}_{it} = \frac{1}{|A_{it}|} \times \sum_{a \in A_{it}} \text{Year of Disappearance}_j$$

$$\text{Median Vintage}_{it} = \frac{1}{|A_{it}|} \times \sum_{a \in A_{it}} v_{j(a)}^{0.50}$$

- A_{it} set of ads posted by firm i in year t

Empirical Setup

$$
\begin{aligned}
x_{it} = \beta_t &+ \beta_1 \text{Year of Emergence}_{it} + \beta_2 \text{Median Vintage}_{it} \\
&+ \beta_3 \text{Year of Disappearance}_{it} + \beta_n \\
&+ \beta_4 \log k_{it} + \beta_5 \log l_{it} + \beta_6 \log_t y_{it} + \sum_o \beta_o S_{ito} + \epsilon_{it}
\end{aligned}
$$

- x_{it}: Firm-level characteristic
- β_t year fixed effects, β_n industry fixed effects
- k_{it}, l_{it}, y_{it} : capital, labor, revenues,
- S_{ito}: share of firm i's ads in (2-digit) occupation o.

Newer work is not correlated with contemporaneous productivity

Dep. Variable	$\log(y_{it}/l_{it})$		
Year of Emergence $_{it}$		-0.0002 (0.0020)	
Median Vintage$_{it}$	0.0011 (0.0017)		–0.0021 (0.0020)
Year of Disappearance$_{it}$		0.0123 (0.0043)	
Include occup. shares?	No	No	Yes

- No significant difference between contemporaneous productivity and job vintages

Newer work is not correlated with contemporaneous productivity... but is associated with R&D intensity

Dep. Variable	$\log(y_{it}/l_{it})$		$\log(\text{R\&D}_{it}/y_{it})$		
Year of Emergence $_{it}$		-0.0002 (0.0020)		0.033 (0.007)	
Median Vintage$_{it}$	0.0011 (0.0017)		0.030 (0.006)		0.031 (0.006)
Year of Disappearance$_{it}$		0.0123 (0.0043)		0.004 (0.011)	
Include occup. shares?	No	No	No	No	Yes

- A decade difference in job vintage is associated with a 30 log point difference in R&D intensity

Newer work is also predictive of future growth

Dep. Variable	$\log(y_{i,t+5}/y_{it})$			$\log(y_{i,t+10}/y_{it})$		
MedianVintage	0.010	0.009	0.008	0.016	0.014	0.013
Year_{it}	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
$\log(\text{patents}_{i,t}$		-0.012	-0.013		-0.017	-0.020
$+1)$		(0.007)	(0.008)		(0.010)	(0.011)
$\log(\text{R\&D}_{it}/y_{it})$		0.007	0.007		0.010	0.011
		(0.002)	(0.002)		(0.003)	(0.003)
Include occup. shares?	No	No	Yes	No	No	Yes

- A decade difference in job vintage is associated with 10 log points faster growth over 5 years, 16 log points over 10 years

Unlike for other measures of innovation, new work is associated with young firms

Dep. Variable	Firm Age$_{it}$					
Median Vintage$_{it}$	-0.694 (0.124)		-0.841 (0.121)		-1.159 (0.161)	-1.173 (0.160)
$\log(\text{patents}_{it}+1)$		5.079 (0.363)	5.277 (0.372)			3.920 (0.455)
$\log(\text{R\&D}_{it}/y_{it})$				0.237 (0.131)	0.319 (0.128)	-0.075 (0.143)
Include occup. shares?	No	No	Yes	No	No	Yes

- Firms with newer vintages are younger; those who patent more or have high R&D intensity are older.

Summary so far

New work:

- is correlated with other innovative activities,
- predictive of survival and future growth,
- occurs in young firms
  - Contrary to patenting and having high R&D intensity: occurs in old firms

Other exercises

- Among all firms, new work is associated with being publicly traded, patenting more frequently, having more highly cited patents.

- Among privately held firms, firms posting ads for new work are more likely to go public in the future

Outline

1. Data set and job vintage measures
2. Job title vintage is an indicator of innovative, high-skilled activity.
3. Job title is predictive of future firm performance
4. **Synergies and heterogeneity across groups of occupations**

We separately measure vintages by groups of occupations

We group 2-digit occupations into three categories:

- Technological
  - SOC 15: Computer Programmers
  - SOC 17: Engineers and Architects
- Organizational:
  - SOC 11: Management
  - SOC 13: Business and Finance
  - SOC 23: Legal
  - SOC 41: Sales
  - SOC 43: Office and Administrative Support
- All Other ("Production") Occupations

Firms hiring new vintage jobs in one domain also do so in others

Dep. Variable	Median Vintage: Organizational$_{it}$			Median Vintage: Technological$_{it}$		
Median Vintage: Non-Organizational$_{it}$	0.048	0.061	0.016			
	(0.021)	(0.011)	(0.010)			
Median Vintage: Non-Technological$_{it}$				0.076	0.068	0.025
				(0.036)	(0.022)	(0.022)
Sample	Public	Public + Private		Public	Public + Private	
Firm Fixed Effects	No		Yes	No		Yes

Firms' R&D intensity is associated with organizational jobs' vintages, sales growth is associated with vintages in "Other" Occupations

Dep. Variable	$\log(\text{R\&D}_{it}/y_{it})$			$\log(y_{f,t+5}/y_{it})$		
Median Vintage:	0.054		0.043	0.0024		0.0009
Organizational$_{it}$	(0.013)		(0.018)	(0.0018)		(0.0023)
Median Vintage:		0.007	0.005		0.0043	0.0037
Technological$_{it}$		(0.013)	(0.015)		(0.0016)	(0.0018)
Median Vintage:			0.023			0.0055
All Other Occupations$_{it}$			(0.012)			(0.0014)

- 10 years newer for organizational ("other") jobs is associated with a 4 percent increase in R&D intensity (and a 5 percent increase in sales growth).

Younger firms and publicly traded firms have newer vintage organizational jobs.

Dep. Variable	Age_{it}			Public_{it}		
Median Vintage:	-0.410		-0.425	0.0068		0.0072
$\text{Organizational}_{it}$	(0.089)		(0.126)	(0.0012)		(0.0018)
Median Vintage:		-0.265	-0.254		0.0034	0.0036
$\text{Technological}_{it}$		(0.125)	(0.138)		(0.0013)	(0.0014)
Median Vintage:			-0.105			0.0050
$\text{All Other Occupations}_{it}$			(0.101)			(0.0013)

- 10 years newer for organizational jobs is associated with a 4 year reduction in firm age, a 0.7 p.p. increase in the probability of being publicly traded.

Conclusion

This paper provides a new measure of adoption to new technologies

Our measure correlates with innovativeness and firm success

- Public firms which place ads for new work
  - are more R&D intensive
  - have faster future sales growth
- Among all firms, new work occurs in younger firms, firms likely to survive in the future.