The Skill Content of Recent Technological Change

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Main Questions

- How have (occupational) skill requirements changed in recent decades and how are these changes related to technological change?

- To what extent do skill requirement changes explain the observed educational upgrading in recent decades?

- To what extent do gender specific skill requirement changes explain the observed changes in the gender wage gap?

Task Framework
(Autor, Levy and Murnane, QJE 2003)

- Conceptualize work as a series of tasks

- Classify tasks from a "machine's-eye" perspective in routine and non-routine

- Computers substitute for workers in carrying out routine tasks (routine manual and routine cognitive)

- Computers complement workers in carrying out non-routine analytical and interactive tasks

→ **Mechanism that underlies the "black box" of skill-biased Technological change**

Qualification and Career Survey

- Individual-level data set launched jointly by BIBB and IAB.

- 4 independent cross-sections (1979, 1985/86, 1991/92, 1998/99).
(Most recent wave from 2006 will soon be publicly available; BIBB and BAuA)

- Between 23,000 and 28,000 individuals per wave.

- Information on the task composition of jobs, on technology, and on human capital of individuals.

- The occupational titles are constant over time.

Table 1: Assignment of Activities

Classification	Tasks
Non-routine analytic	researching/analyzing/evaluating and planning, making plans/constructions/designing and sketching, working out rules/prescriptions, using and interpreting rules
Non-routine interactive	negotiating/lobbying/coordinating/organizing, teaching/training, selling/buying/advising customers/advertising, entertaining/presenting, employ/manage personnel
Routine cognitive	calculating/bookkeeping, correcting of texts/data, measuring of length/weight/temperature
Routine manual	operating/controlling machines, equipping machines
Non-routine manual	repairing/renovation of houses/apartments/machines/vehicles, restoring of art/monuments, serving or accommodating

Task Measure

$$Task_{ijt} = \frac{\text{number of activities in category j performed by i in cross-section t}}{\text{total number of activities in category j at time t}} * 100$$

where

$t =$ 1979, 1984/85, 1991/92 and 1998/99

$$j = \begin{cases} 1 : \text{analytic tasks} \\ 2 : \text{interactive tasks} \\ 3 : \text{routine cognitive tasks} \\ 4 : \text{routine manual tasks} \\ 5 : \text{non-routine manual tasks} \end{cases}$$

Table 2
Descriptive Figures on Educational Trends and Computer Diffusion (%)

	1979	1985/86	1991/92	1998/99
	A. Proportion of Different Educational Groups in Employment			
High level of education	8.18	10.20	13.30	16.48
Medium level of education	72.38	68.33	71.28	70.57
Low level of education	21.84	21.47	15.42	12.95
	B. Spread of Computers, Terminals, Laptops, and Electronic Data-Processing Devices			
Overall	6.06	18.11	34.52	55.38
High level of education	12.22	25.58	60.73	83.15
Medium level of education	6.31	20.00	33.77	56.52
Low level of education	3.44	10.19	16.13	32.65

NOTE.—Sample includes workers aged 18–65 who lived in West Germany and were German nationals.

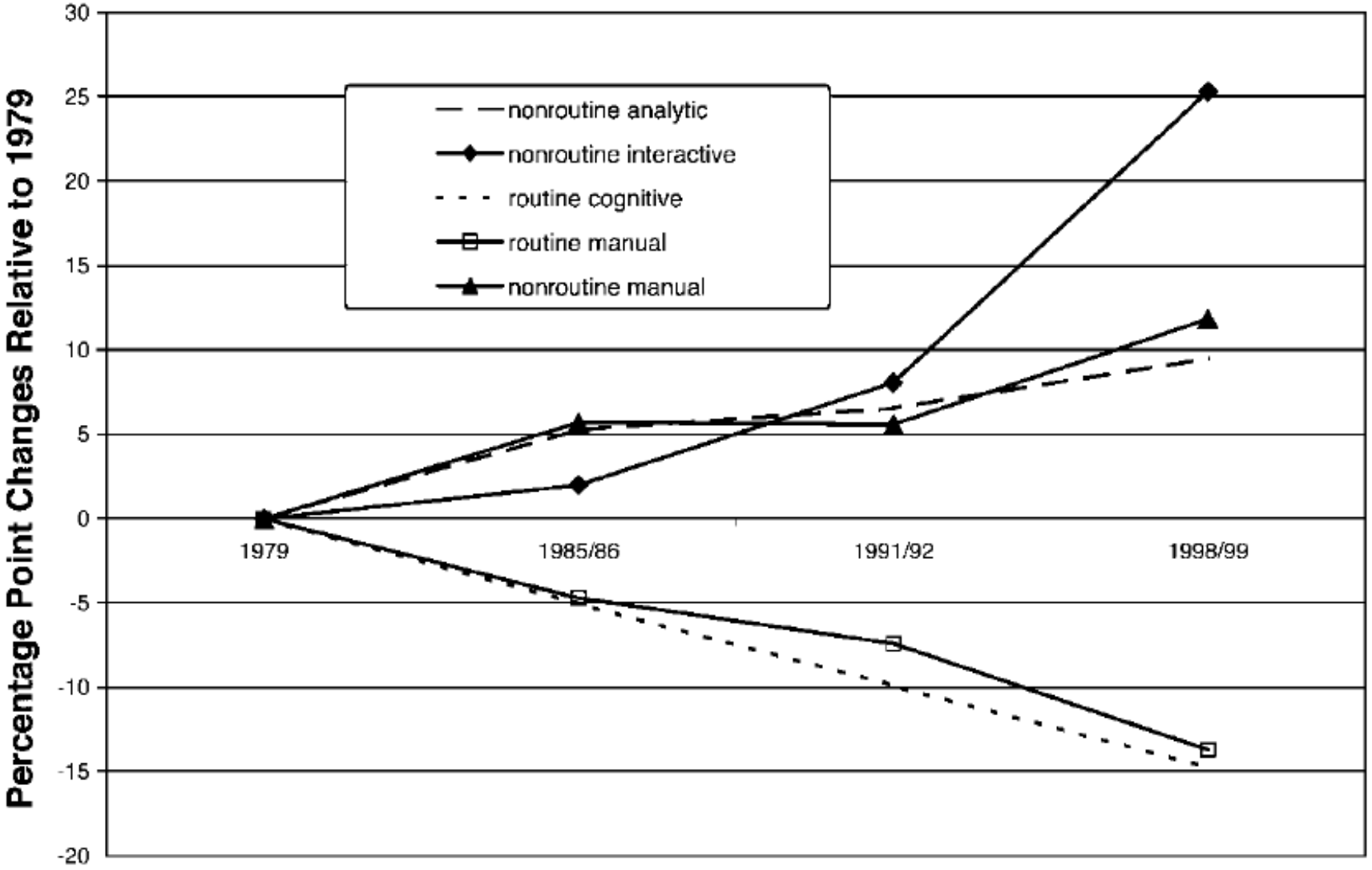


FIG. 1.—Trends in aggregate skill inputs

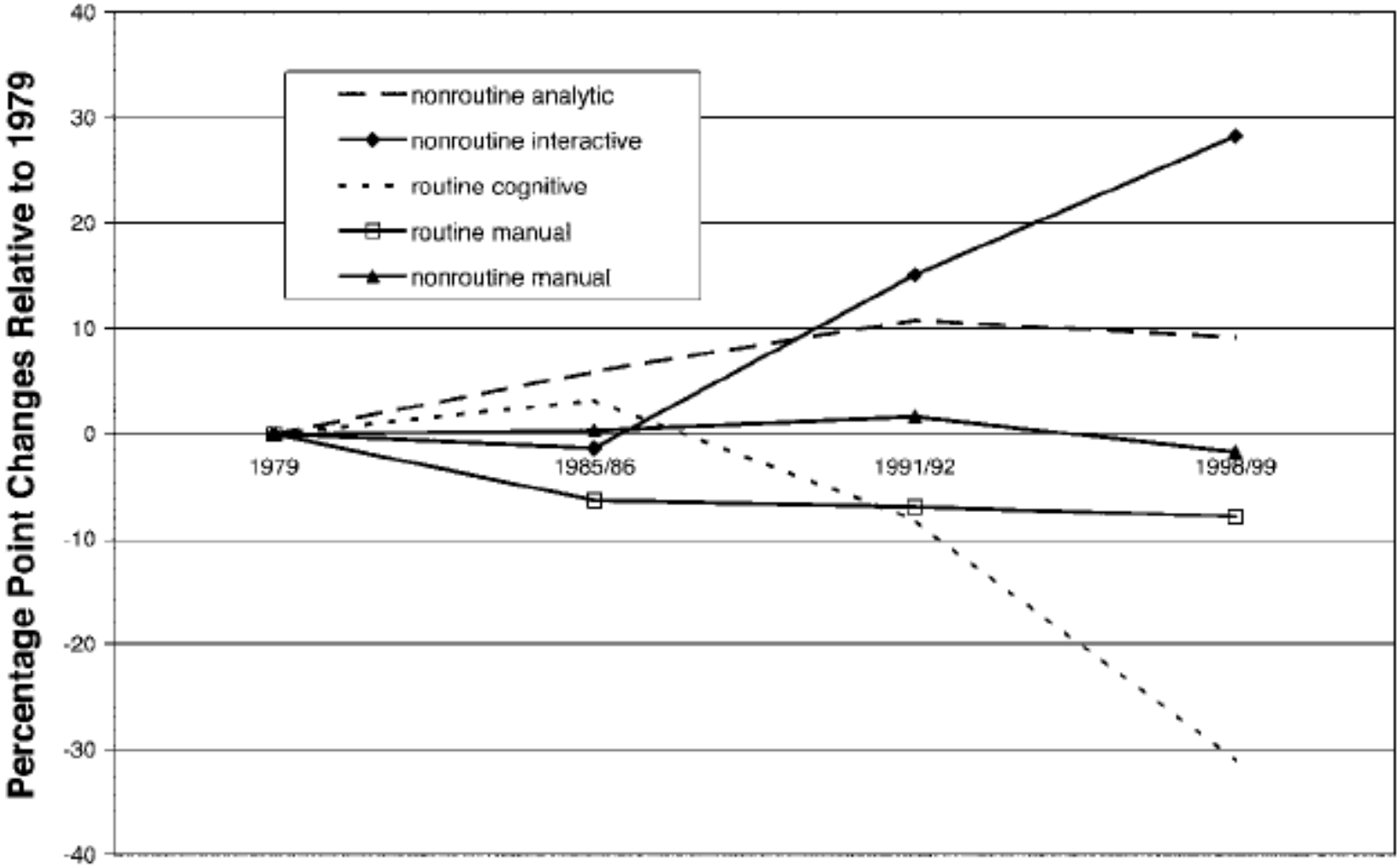


FIG. 2.—Employees with high levels of education: trends in aggregate skill inputs

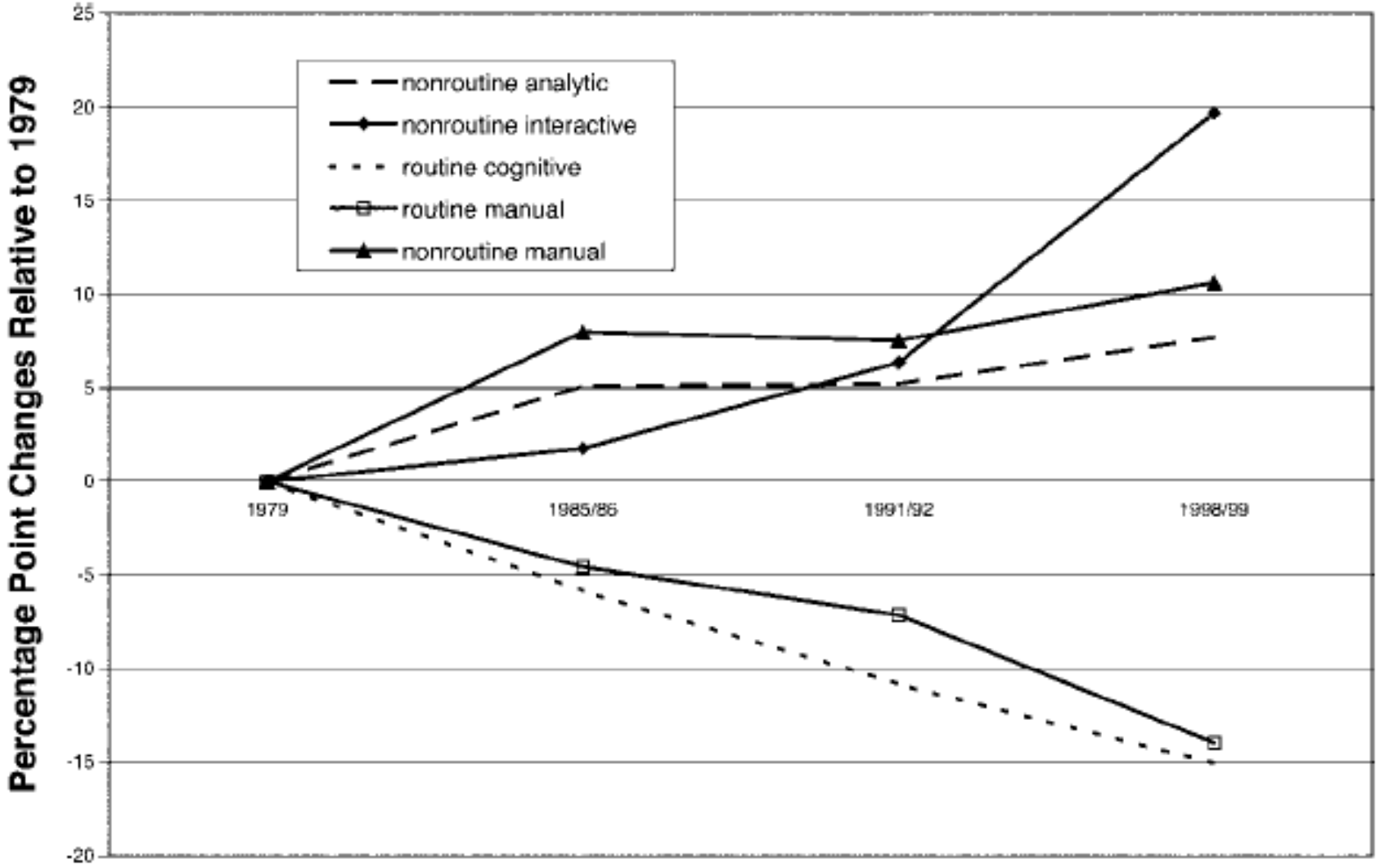


FIG. 3.—Employees with medium levels of education: trends in aggregate skill inputs

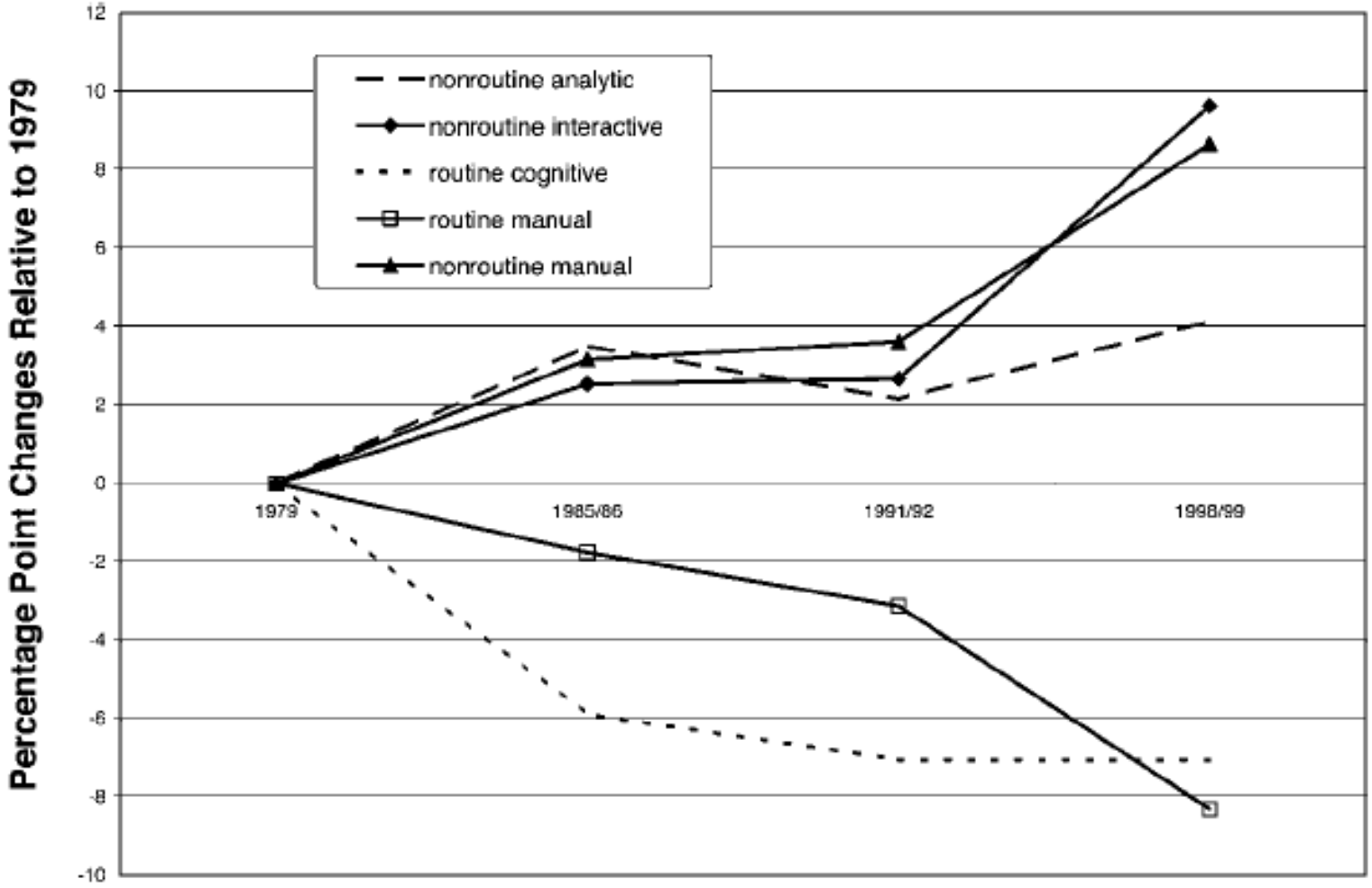


FIG. 4.—Employees with low levels of education: trends in aggregate skill inputs

Table 4
Trends in Aggregate Skill Inputs by Birth Cohorts (%)

Year of Birth	1979	1985/86	1991/92	1998/99
Nonroutine analytical task inputs:				
1975–81				7.41
1969–74			7.71	11.54
1962–68		5.58	10.16	14.63
1956–61	2.39	9.72	13.35	15.09
1950–55	5.15	11.16	12.69	13.95
1940–49	5.49	11.23	11.22	15.32
Before 1940	4.23	9.47	8.76	16.56
10 × average annualized changes 1979–1998/99:				
Within cohorts	5.90			
Within age levels	4.89			
Nonroutine interactive task inputs:				
1975–81				23.17
1969–74			9.52	30.35
1962–68		6.25	15.05	33.61
1956–61	5.72	10.13	18.36	34.37
1950–55	8.77	11.96	20.14	36.68
1940–49	9.90	11.95	17.81	37.26
Before 1940	8.48	10.65	14.15	36.98
10 × average annualized changes 1979–1998/99:				
Within cohorts	18.33			
Within age levels	16.61			

Year of Birth	1979	1985/86	1991/92	1998/99
Routine cognitive task inputs:				
1975–81				22.44
1969–74			22.21	21.41
1962–68		25.06	28.86	24.01
1956–61	38.04	33.08	29.04	23.54
1950–55	42.08	35.72	29.69	20.57
1940–49	39.87	33.99	27.73	19.22
Before 1940	32.36	29.43	21.45	23.05
10 × average annualized changes 1979–1998/99:				
Within cohorts	−6.11			
Within age levels	−7.01			
Routine manual task inputs:				
1975–81				18.97
1969–74			29.80	17.23
1962–68		31.51	25.23	19.15
1956–61	41.53	27.21	24.99	17.68
1950–55	35.13	26.05	21.80	15.19
1940–49	30.52	23.91	20.87	14.71
Before 1940	25.21	24.80	22.91	17.61
10 × average annualized changes 1979–1998/99:				
Within cohorts	−10.47			
Within age levels	−8.39			

Year of Birth	1979	1985/86	1991/92	1998/99
Nonroutine manual task inputs:				
1975–81				30.28
1969–74			25.23	27.78
1962–68		22.83	22.36	25.94
1956–61	15.42	20.78	20.18	25.69
1950–55	14.18	18.05	18.35	25.68
1940–49	13.39	18.91	17.31	24.45
Before 1940	14.25	19.74	19.37	23.30
10 × average annualized changes 1979–1998/99:				
Within cohorts	4.68			
Within age levels	6.57			

Table 5
Shift-Share Analysis of Changes in Skill Requirements

	Overall				
	Nonroutine Analytic	Nonroutine Interactive	Routine Cognitive	Routine Manual	Nonroutine Manual
1979–85	8.82	3.35	−8.43	−7.83	9.52
1985–91	2.12	10.12	−8.05	−4.50	−.21
1991–99	4.21	24.63	−6.94	−8.98	8.94
1979–99	5.01	13.34	−7.76	−7.20	6.23

	Between and Within Occupational Decomposition									
	Btwn	Wthn	Btwn	Wthn	Btwn	Wthn	Btwn	Wthn	Btwn	Wthn
1979–85	−.27	9.10	.15	3.21	−1.40	−7.03	−1.26	−6.57	.77	8.75
1985–91	.44	1.68	.10	10.02	.87	−8.92	−.00	−4.50	.34	−.55
1991–99	2.67	1.55	5.24	19.39	.06	−7.00	−6.04	−2.94	−.97	9.91
1979–99	.77	4.24	1.70	11.64	−.06	−7.70	−.98	−6.22	.12	6.11

Table 6
Bivariate Regressions: Technological Change and Changes in Skill Requirements

	Nonroutine Analytic	Nonroutine Interactive	Routine Cognitive	Routine Manual
A:				
Δ computer use	.086***	.188***	−.312***	−.561***
	(.032)	(.031)	(.105)	(.148)
Dummy 1985/86–1991/92	−6.160***	3.536**	−1.960	−2.462
	(1.129)	(1.767)	(3.098)	(7.712)
Dummy 1991/92–1998/99	−7.987***	8.915***	16.394**	−7.436
	(1.381)	(1.440)	(7.726)	(7.065)
R^2	.183	.337	.079	.131
No. of observations	237			

Contribution of Task Changes to Educational Upgrading

$$ED_{ict} = \alpha_{0it} + \sum_{j=1}^{4} S_{jct}\alpha_{ijt} + \upsilon_{ict},$$

$$\widehat{\Delta ED}_{ict} = \sum_{j=1}^{4} \Delta S_{jc\tau}\hat{\alpha}_{ij(t-1)},$$

Table 9
Shifts in High-Educated-Equivalent and Medium-Educated-Equivalent Labor Demand Implied by Changes in Occupational Skill Requirement

	1979–1985/86	1985/86–1991/92	1991/92–1998/99	1979–1998/99
	A. Estimated Log Demand Shifts for Employees with High (Medium)/Low Levels of Education (100 × Annual Log Changes; $\sigma = 1.4$)			
High/low level of education	5.587	6.728	5.986	6.095
Medium/low level of education	−.774	5.326	2.755	2.452
	B. 10 × Observed Annual Changes in Within-Occupation Skill Requirements			
Nonroutine analytic	9.037	1.716	1.774	4.242
Nonroutine interactive	3.046	9.981	16.430	10.705
Routine cognitive	−6.059	−9.054	−10.416	−8.965
Routine manual	−5.875	−5.216	−4.028	−7.305

	C. Predicted Proportion of Changes in Demand for Employees with High (Medium) Levels of Education Explained by Observed Changes in Within-Occupation Skill Requirements (%)			
High level of education	31.458	25.555	42.933	35.969
Medium level of education	77.828	−8.291	−20.946	−24.987
	D. Predicted Annual Changes in Occupational Skill Requirements Implied by Computerization (10 × Annual Changes)			
Nonroutine analytic	8.901	2.991	.519	4.129
Nonroutine interactive	4.243	9.572	15.013	9.664
Routine cognitive	−5.547	−9.001	6.519	−2.375
Routine manual	2.171	−.134	−4.503	−.964

	E. Predicted Proportion of Changes in Demand for Employees with High/Medium Levels of Education Explained by Predicted Changes in Occupational Skill Requirements Implied by Computerization (%)			
High level of education	30.967	25.603	35.438	30.638
Medium level of education	58.882	−7.046	−16.895	−17.831

Conclusions (Part I)

• Occupations today involve greater complexity than they did 2 decades ago.

• Ubiquitous phenomenon occurring within occupations, within occupation-education, and within occupation-age groups.

• Changes have been intensified by the diffusion of computer technology in the workplace.

• West Germany has experienced changes in skilll requirements similar to those in the U.S. in recent decades.

Table 2: Summary Statistics: Full-Time Workers Only
(Standard Deviations in Parentheses)

	Analytic	Interactive	Routine Cognitive	Routine Manual	Non-Routine Manual	PC Use
Male						
1979	8.3	13.3	48.8	31.0	23.4	7.8
(N=12,361)	(16.2)	(16.1)	(44.8)	(41.1)	(37.4)	(26.9)
1999	17.3	35.4	40.9	21.9	48.6	65.5
(N=9,986)	(24.2)	(29.1)	(48.5)	(32.7)	(49.1)	(47.5)
Change 1979-1999	9.0	22.1	-7.9	-9.1	15.2	57.7
Female						
1979	2.8	8.6	52.2	59.6	12.5	6.2
(N=6,389)	(9.6)	(11.4)	(46.9)	(44.5)	(28.8)	(24.0)
1999	12.9	34.2	24.0	9.9	56.1	61.6
(N=5,989)	(20.8)	(25.7)	(41.8)	(23.4)	(48.0)	(48.6)
Change 1979-1999	10.1	25.6	-28.2	-49.7	43.6	55.4
Difference (Male-Female)						
1979	5.5	4.7	-3.4	-28.6	10.9	1.6
	(.2)	(.2)	(.7)	(.6)	(.5)	(.4)
1999	4.4	1.2	16.8	11.9	-7.5	3.9
	(.4)	(.5)	(.8)	(.5)	(.8)	(.8)

Role of Changing Tasks on the Gender Wage Gap

• Gender wage gap declined by about 9 percentage points in West Germany between 1979 and 1999.

• Predict how wages of men and women would have evolved if task prices and other characteristics had remained constant but tasks had changed.

• Fixed-Coefficient Model (holding task prices constant at 1979 prices).

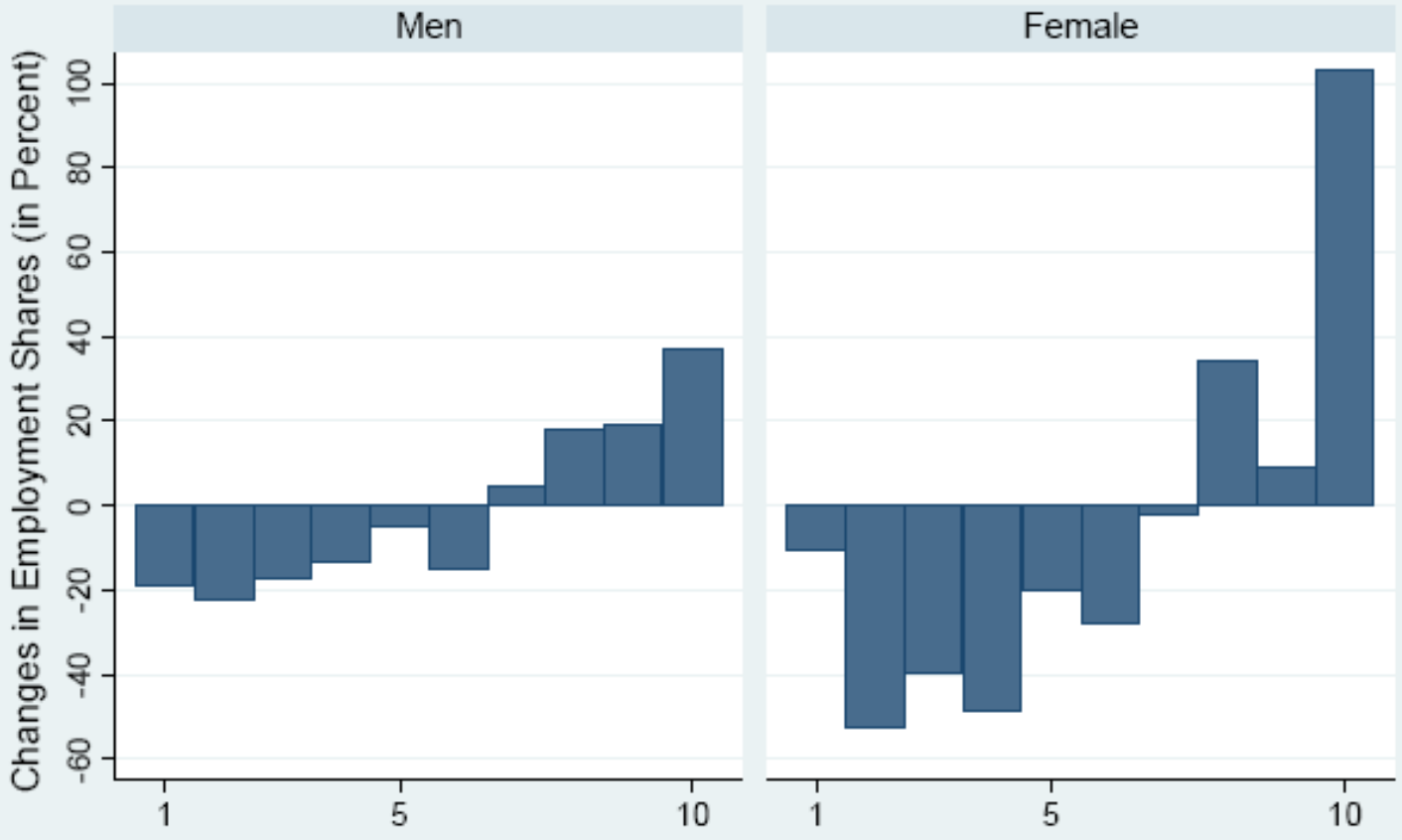
• Result: about 50 percent of closing of gender pay gap is explained by differential task changes across genders alone.

Polarization

• Task framework predicts that it is jobs that employ middle educated workers that are going to be most affected by computerization.

• This will lead to a hollowing-out of the distribution of jobs by skill.

• Given the large relative decreases in routine tasks and the large relative increases in non-routine manual tasks experienced by women, polarization should be more pronounced for them.



Note: The figure shows percentage changes in (full-time) employment shares between 1979 and 1999 for occupations that are ranked in 10 groups according to their median wages in 1979.
Data: IAB Employment Sample

Figure 3: Changes in Employment Shares by 1979 Median Wages

Conclusions (Part II)

- The change in women's work relative to that of men is more pronounced at each task dimension
- Women gained on men with respect to analytical and interactive tasks and also with respect to routine tasks
- The task changes can explain a substantial fraction of the decline in the gender wage gap over this period
- The task changes for both genders are consistent with workplace computerization playing a significant role