Skill Demand, Inequality and Computerization:

Connecting the Dots

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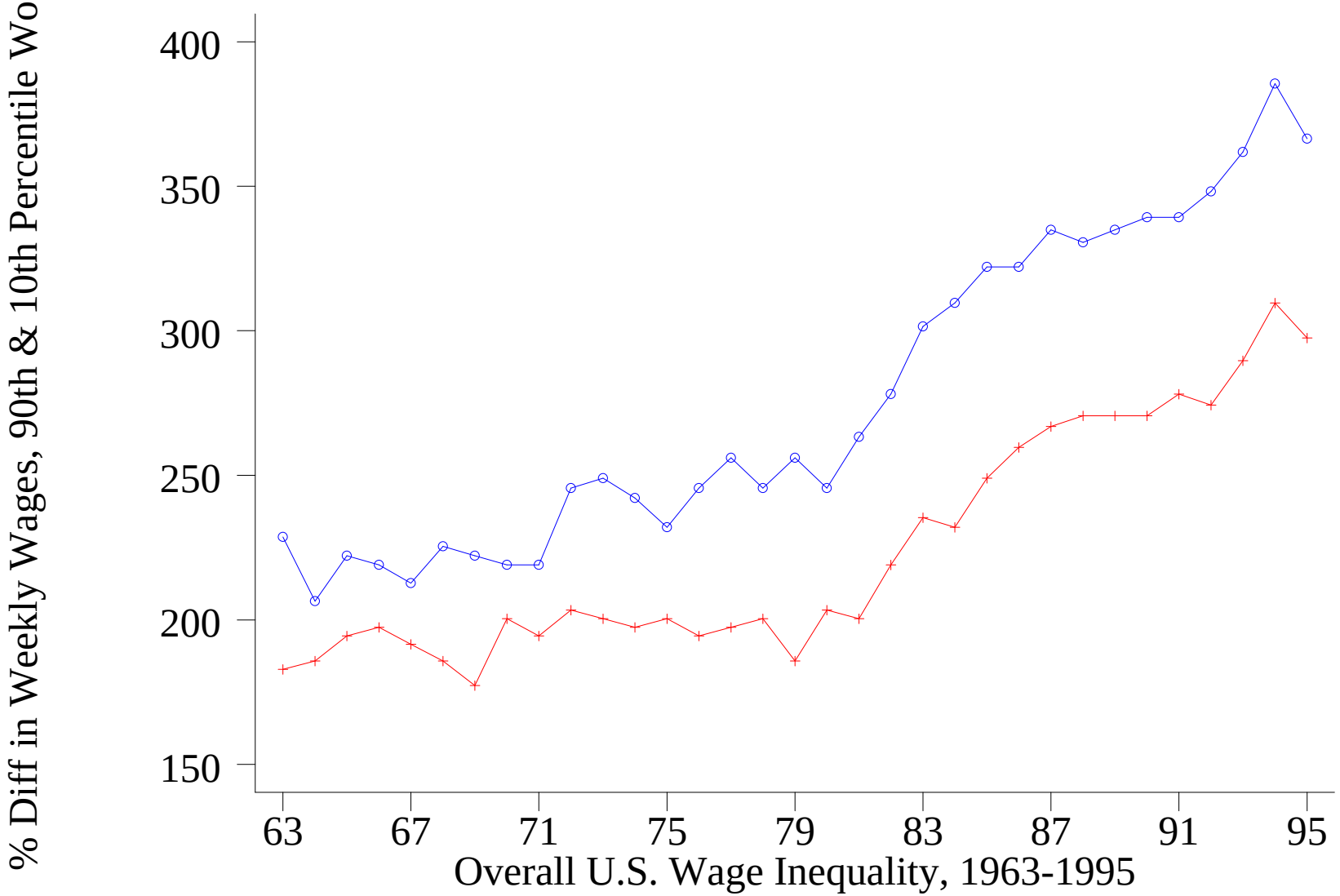
Dramatic shifts in relative well-being demand attention…

- Late 1980s: Economists noticed earnings of high and low wage workers rapidly diverging.
- 1963 to 1979: the 90/10 earnings differential hovered steadily at approximately 220 percent among men, 190 percent among women.
- 1979 to 1989: this differential expanded by 110 percentage points for both sexes, edged upward slowly therafter.

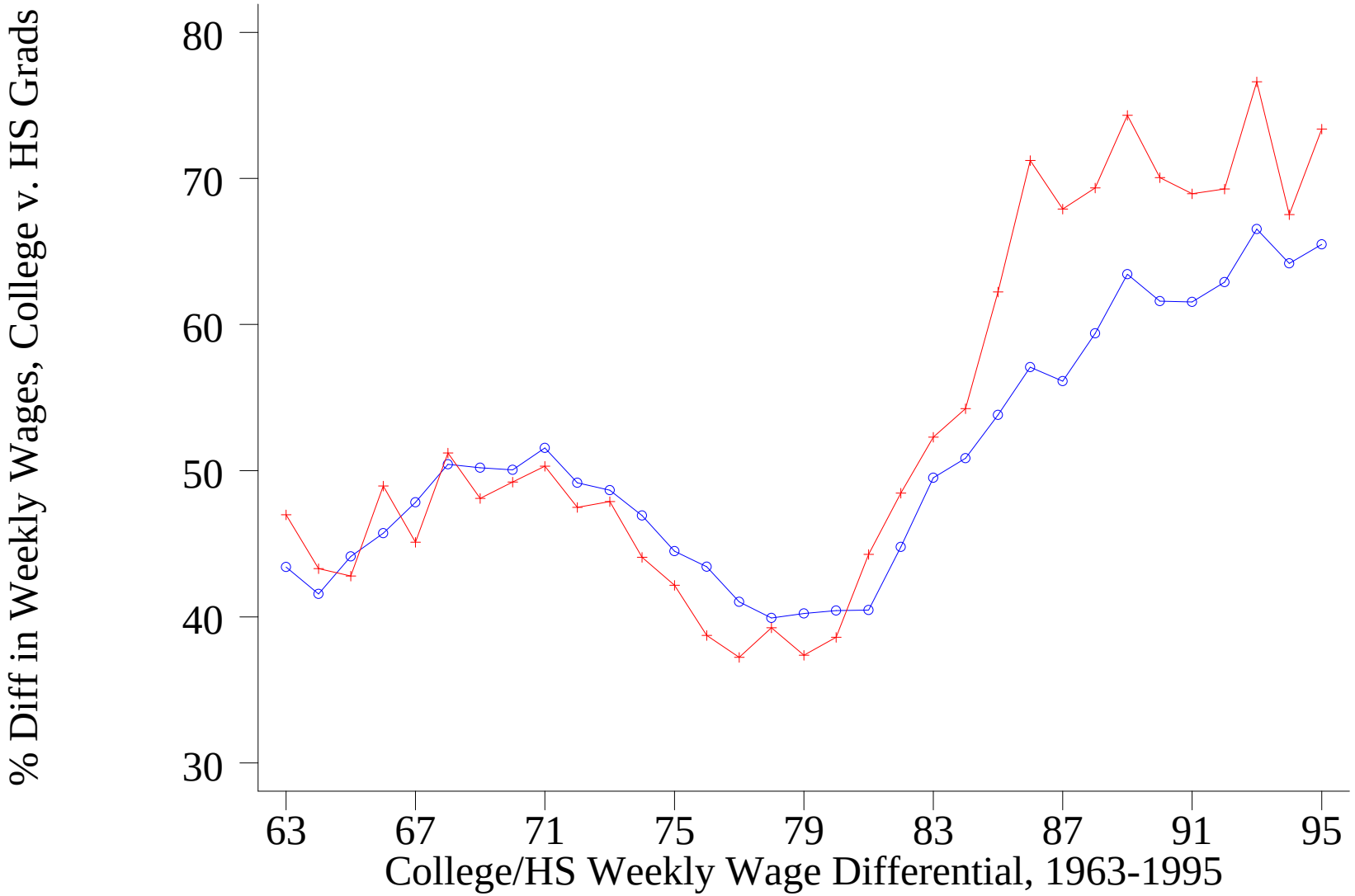
Figure 1. (o) Males (+) Females
Source: Katz & Autor, 1999



Mirroring these trends

- *Educational* earnings inequality – the college/high school earnings gap – increased by 70 percent between 1979 and 1995.
- By 1999, educational inequality exceeded its high set in 1940, the earliest year for which consistent data are available.

Figure 2. (o) All (+) 5 Years Experience
Source: Katz & Autor, 1999



Natural suspect: Factors influencing demand and supply for skills

- *Skill Biased Technical Change (SBTC)*: Change in how work accomplished that raises productivity of more relative less skilled workers.
- Productivity gains

  $\Rightarrow$ Greater demand for high skilled workers' services

  $\Rightarrow$ Enhanced earnings power

  $\Rightarrow$ Greater earnings inequality.

Hypothesis has obvious appeal:

- Rapid growth of inequality coincided with the advent of desktop computing
- Economists posited that *something* about computerization had made skilled workers relatively more productive.

But three steps missing to SBTC argument:

1. SBTC implies that rising *demand* caused greater inequality. But wages – and hence inequality – determined by *demand and supply*.

   Cogent model of inequality must consider demand & supply simultaneously.

2. History: Demand for educated workers has been growing for decades.

   Was there an acceleration in demand in recent decades?

3. If so, further leap to assume that computerization explains demand shifts.

   What do computers do – or what do people do with computers – that increases demand for more skilled relative to less skilled workers?

Agenda: Connecting the Dots

Objectives of this paper

1. A model of inequality:

   The Demand and Supply for skills.

2. Historical context:

   Did demand for skills accelerate during the computer era?

3. Linking computerization to skill demands:

   How does computerization affect what skills are demanded?

1. Model of Inequality: The Demand and Supply for Skills

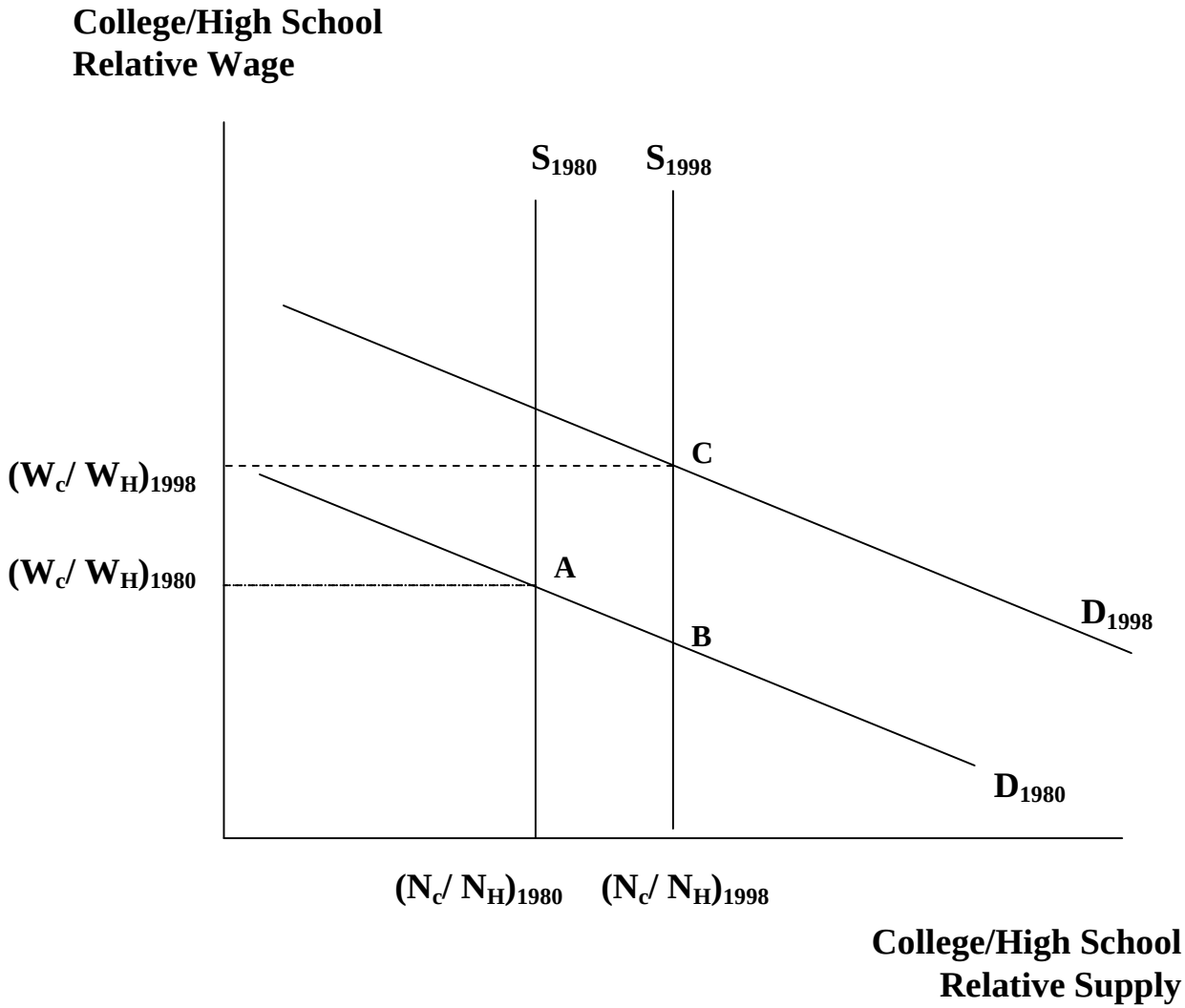
What drives inequality?

- Minimum wages, labor unions, international trade, regulation.
- A logical starting point: *Supply and demand for skill(s).*

Model: Key ideas

- Use College & High School graduates as short-hand for high and low skilled.
- At point in time, ratio of college to high school grads available for work fixed.
- Relative wage of college versus high school graduates are set competitively.
- Measure of inequality: Percentage difference in hourly earnings between college and high school graduates.

Figure 3. Impact of Demand and Supply Shifts on
the Relative Earnings of College vs. High School Graduates



Key facts: 1980 and 1998

- Share of High School grads in employment *fell* from 36 to 33 percent.
- Share of College grads in employment *rose* from 31 to 43 percent.
- Average wage difference between College/HS *rose* from 48 to 75 percent.

Implication: *Relative demand for College vs. HS grads rose.*

- How much? Depends on *elasticity of substitution*.
- The easier it is for businesses to substitute High School for College grads, the less College grad wages rise for a given demand shift.
- Using elasticities of 1 to 2, relative demand increased by 3.4 to 4.4 percentage points annually from 1980 – 1998.
- *Substantial demand shifts during period when earnings inequality rising.*

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Historical context: Did demand *accelerate* during the computer era?

Do facts imply that earnings inequality caused by sudden demand shift?

- *Not necessarily*. Need historical context.
- Table 1:
  - In 1940, less than 10 percent of the workforce held a college degree.
  - By 1998, this share exceeded 40 percent.
  - College grads earned 37 to 75 percent more than HS grads in each decade.
- *Relative demand for college graduates growing since at least 1940.*
- Key question: has SBTC *accelerated* demand growth for college graduates recently, causing era of *demand driven* inequality?

Table 1. Full Time Equivalent Employment Shares and Relative Wages of College and High School Graduates 1940 - 1998

	High School Graduates	College Equivalents	College/High School Wage Differential
1940	19.1%	9.3%	64.6%
1950	24.3%	12.4%	36.7%
1960	27.4%	16.4%	48.6%
1970	34.1%	21.5%	59.3%
1980	35.8%	31.3%	47.8%
1990	37.0%	38.0%	66.1%
1998	33.3%	43.2%	75.4%

Source: Autor, Katz and Krueger, 1998 (updated to 1998 data). Data source for 1940 - 1980 is Census Public Use Micro Samples. Data source for 1990 - 1998 is Current Population Survey.

Historical context: Did demand *accelerate* during the computer era?

Two certainties:

- Shifts in the growth rate of *supply* of college graduates clearly impacted inequality throughout the past six decades, esp. 70s and 80s.
- Relative demand for college graduates *did* accelerate (40+ %) in the most recent three decades (1970 – 1998) in comparison to the prior three (1940 – 1970).

Two ambiguities:

- *Timing* of acceleration uncertain: 70s or 80s depending on assumed elasticity.
- Surprising *deceleration in 1990s*. A puzzle for SBTC viewpoint.

Table 2. Changes in College Equivalent/Non-College Log Relative Wages, Supply, and Estimated Demand 1940 - 1980.

A. 100 x Annual Log Changes by Decade

	Relative Wage Change	Relative Supply Change	Implied Relative Demand Shift: College vs. HS Grads		
			s = 1.0	s = 1.4	s = 2.0
1940 - 1950	-1.86	2.35	**0.50**	**-0.25**	**-1.35**
1950 - 1960	0.83	2.91	**3.75**	**4.08**	**4.58**
1960 - 1970	0.69	2.55	**3.25**	**3.52**	**3.94**
1970 - 1980	-0.74	4.99	**4.25**	**3.95**	**3.50**
1980 - 1990	1.51	2.53	**4.05**	**4.65**	**5.56**
1990 - 1998	0.36	2.25	**2.61**	**2.76**	**2.98**

B. 100 x Annual Log Changes for Aggregated Time Periods

1940 - 1970	-0.11	2.61	**2.50**	**2.45**	**2.39**
1970 - 1998	0.38	3.33	**3.71**	**3.86**	**4.08**

Source: Autor, Katz and Krueger, 1998 (updated to 1998 data).

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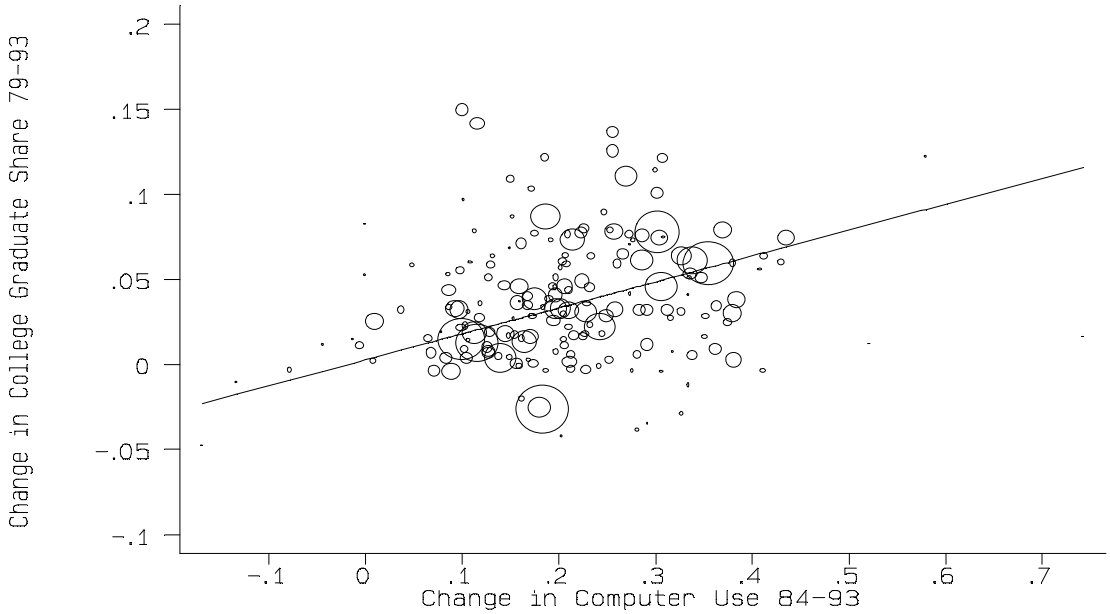
Three pieces of *indirect* evidence:

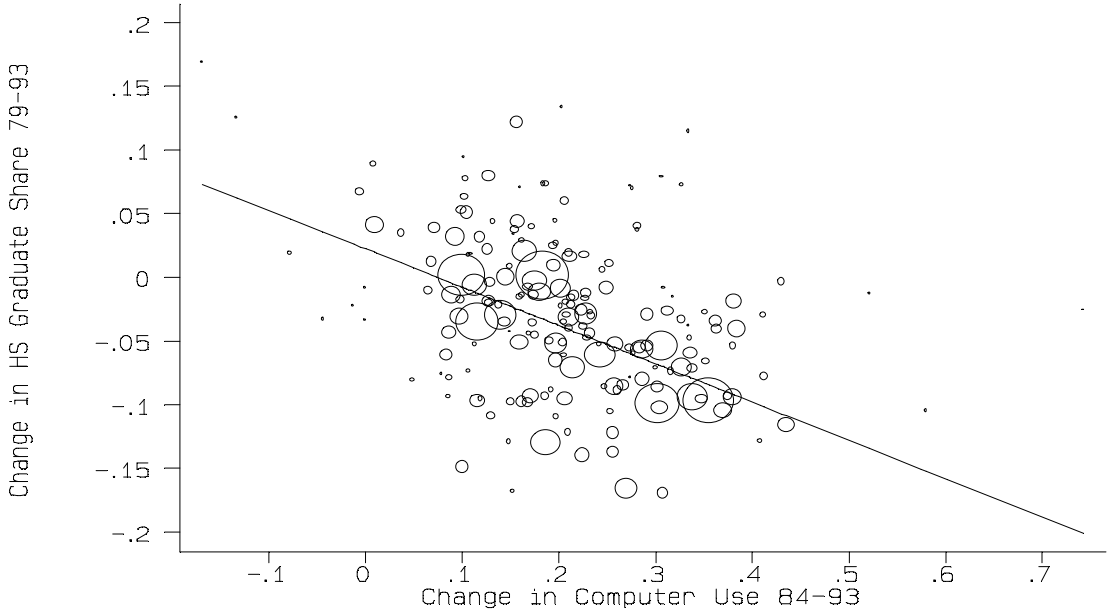
- Business investment in computer equipment per worker rose by 1,800 percent from 1960s to 1970s, and by another 1,500 percent in the 1980s.
- Investment highest in 1990s, but growth *decelerated* in the 1990s.
- Remarkably strong correlation between computerization and changes in the employment shares of educated workers across sectors.

Figure 4. Changes in Computer Use and Industry Work-Force Educational Shares

(a) College Graduates



(b) High School Graduates



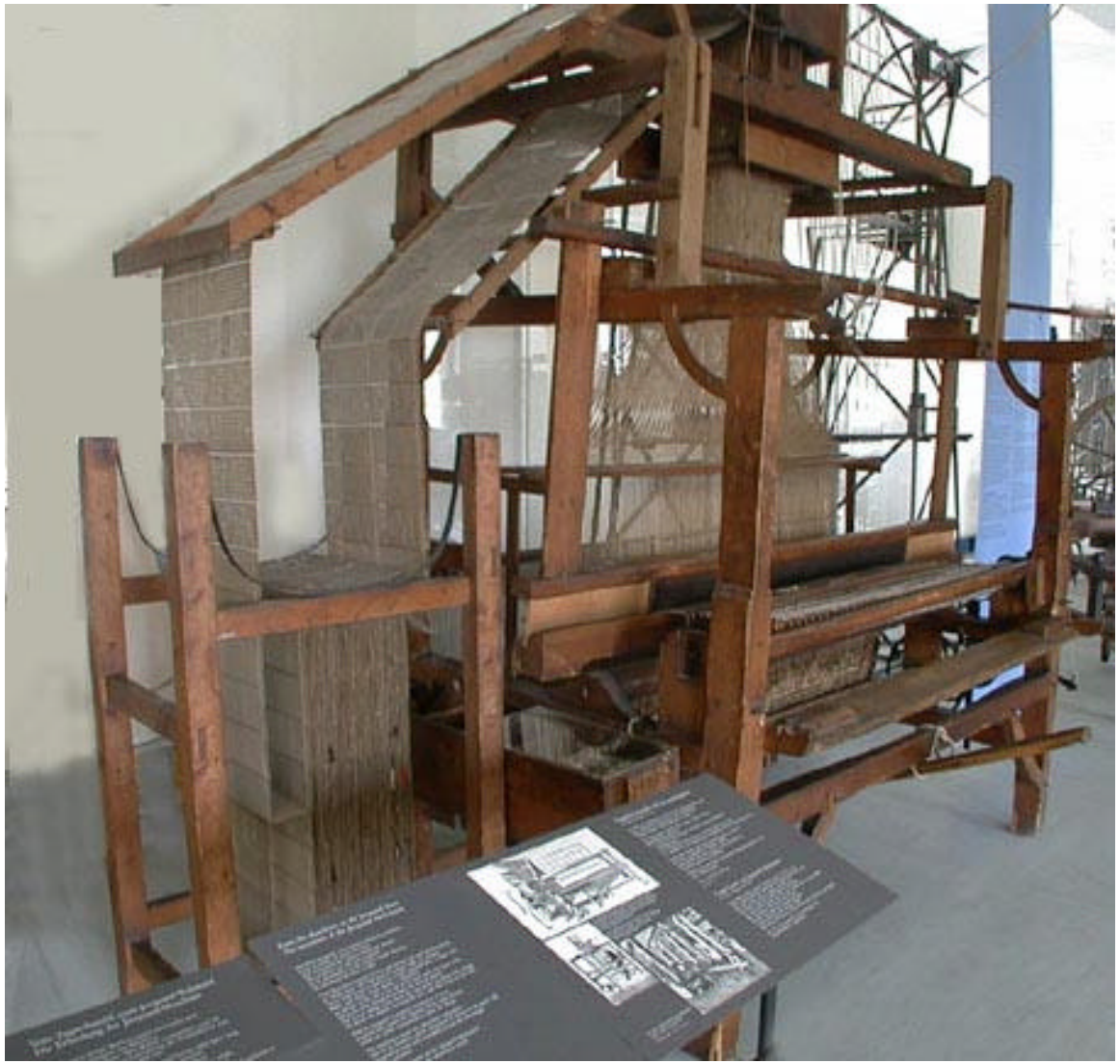
Source: Autor, Katz and Krueger (1998), Figure 1.

Evidence is only circumstantial:

- Links computers to the crime, but missing a 'motive.'
- What is it that computers do – or what is it that people do with computers – that causes educated workers to be relatively more in demand?

More direct approach:

- Conceptualize jobs from machine's eye view: Series of tasks to accomplish.
- Which tasks can be performed by a computer?



Linking Computerization to Skill Demands

Starting point: Jacquard Loom of 1801, 1st digital computer

- Symbolic processor – Acting upon abstract representations of information, e.g., binary numbers or (in loom's case) punched cards.
- Fast, deterministic execution of stored procedures, i.e, programs.

Computing since Jacquard

- Trillion-fold decline in price of computing power.
- Vastly gains in applying loom's core capability to a panoply of tasks.
- *But tasks still cannot be computerized unless they can be proceduralized.*

To which workplace tasks does this capability apply?

- For a large swath of tasks, proceduralization is no hindrance.
- For another critical set, it's a binding constraint.

Table 1: Potential Impact of Computerization on Four Categories of Workplace Tasks.

	Routine Tasks	Non-Routine Tasks
	A. Visual/Manual	
Examples	• Picking and sorting engineered objects on an assembly line. • Reconfiguring production lines to enable short runs.	• Janitorial services. • Truck driving.
Computer Impact	• Computer control makes capital substitution feasible.	• Limited opportunities for substitution or complementarity.
	B. Information Processing/Cognitive	
Examples	• Bookkeeping; • Filing/retrieving textual data; • Processing procedural interactions/ transactions (e.g., bank teller)	• Medical diagnosis; • Legal writing; • Persuading/selling.
Computer Impact	• Substantial substitution.	• Strong complementarities.

Bringing Framework to the Data: Database of job tasks over 4 decades

- Conceptualize jobs as bundle of tasks, not education credentials of jobholders.
- Use 1977 & 1991 *Dictionary of Occupational Titles* to measure tasks.
- First-hand observations of jobs, rated 44 objective/subjective dimensions.
- Append DOT to Census and Current Population Survey files for 1960 to 1998.

Two sources of variation:

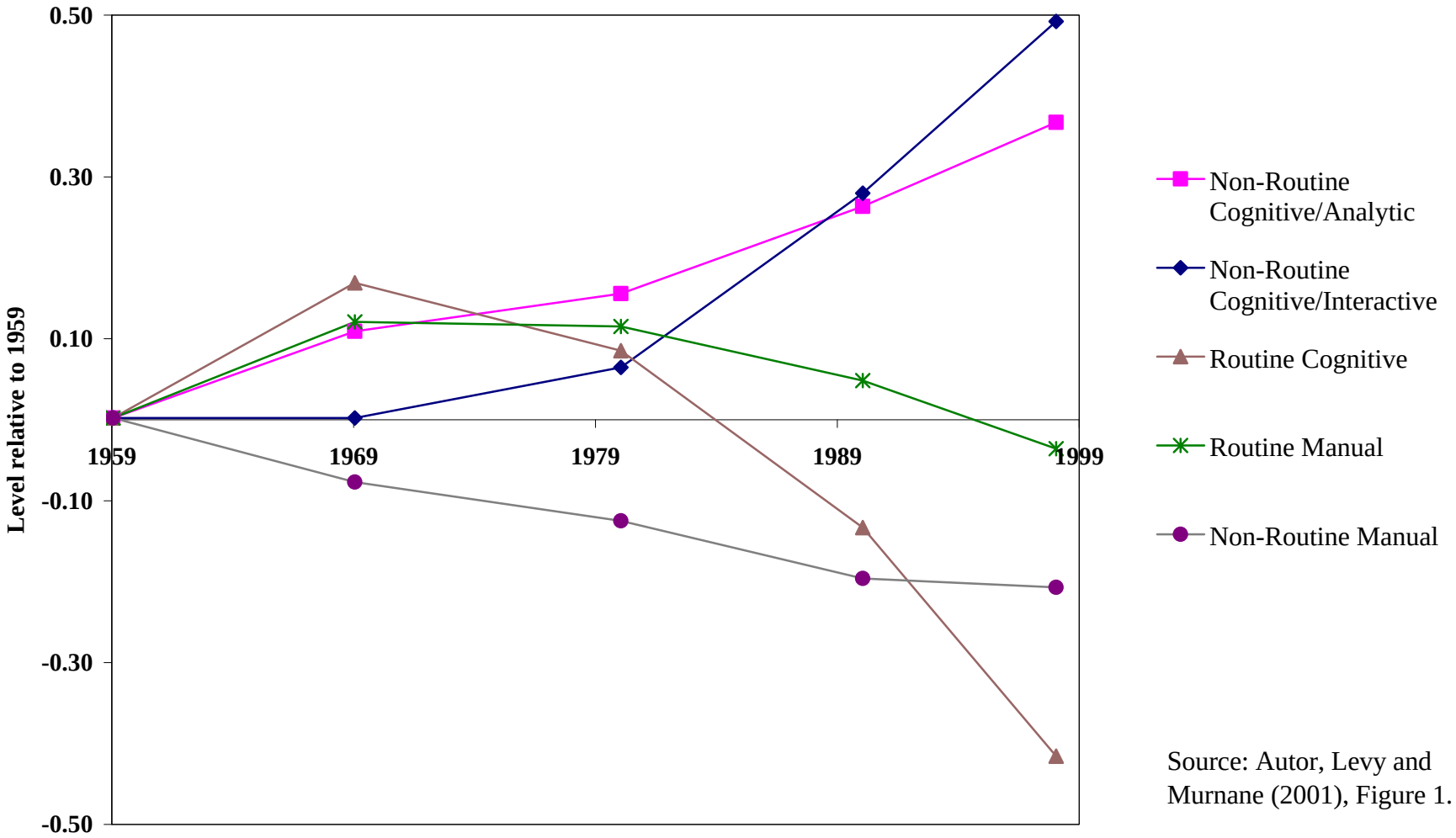
- Changes in the composition of occupations over time.
- Changes in examiners' evaluation of tasks *within* occupations.

Linking Computerization to Skill Demands

Task measures from Dictionary of Occupational Titles:

- Managerial tasks ≈ Non-routine cognitive/interactive skills. (+)
- Math skills ≈ Non-routine cognitive/analytic skills. (+)
- Aptitude for Set limits, Tolerances & Standards ≈ Routine cognitive skills. (–)
- Finger dexterity requirements ≈ Routine manual skills. (–)
- Eye, hand, foot coordination ≈ Non-routine manual skills. (~)

Figure 5. Economy-Wide Measures of Routine and Non-Routine Task Input:
1959 - 1998 (1959 = 0)



Source: Autor, Levy and Murnane (2001), Figure 1.

Linking Computerization to Skill Demands

Three key patterns:

- Share of labor force employed in occupations using non-routine cognitive tasks – both interactive and analytic – increased substantially.
  - *Both trending slightly upward in 60s, accelerated thereafter.*
- Share performing routine cognitive and routine manual activities declined.
  - *Both increased during the 1960s, declined thereafter.*
- Steady trend against non-routine manual tasks pre-dates the computer era.
  - *Consistent with hypothesis of little computer impact.*

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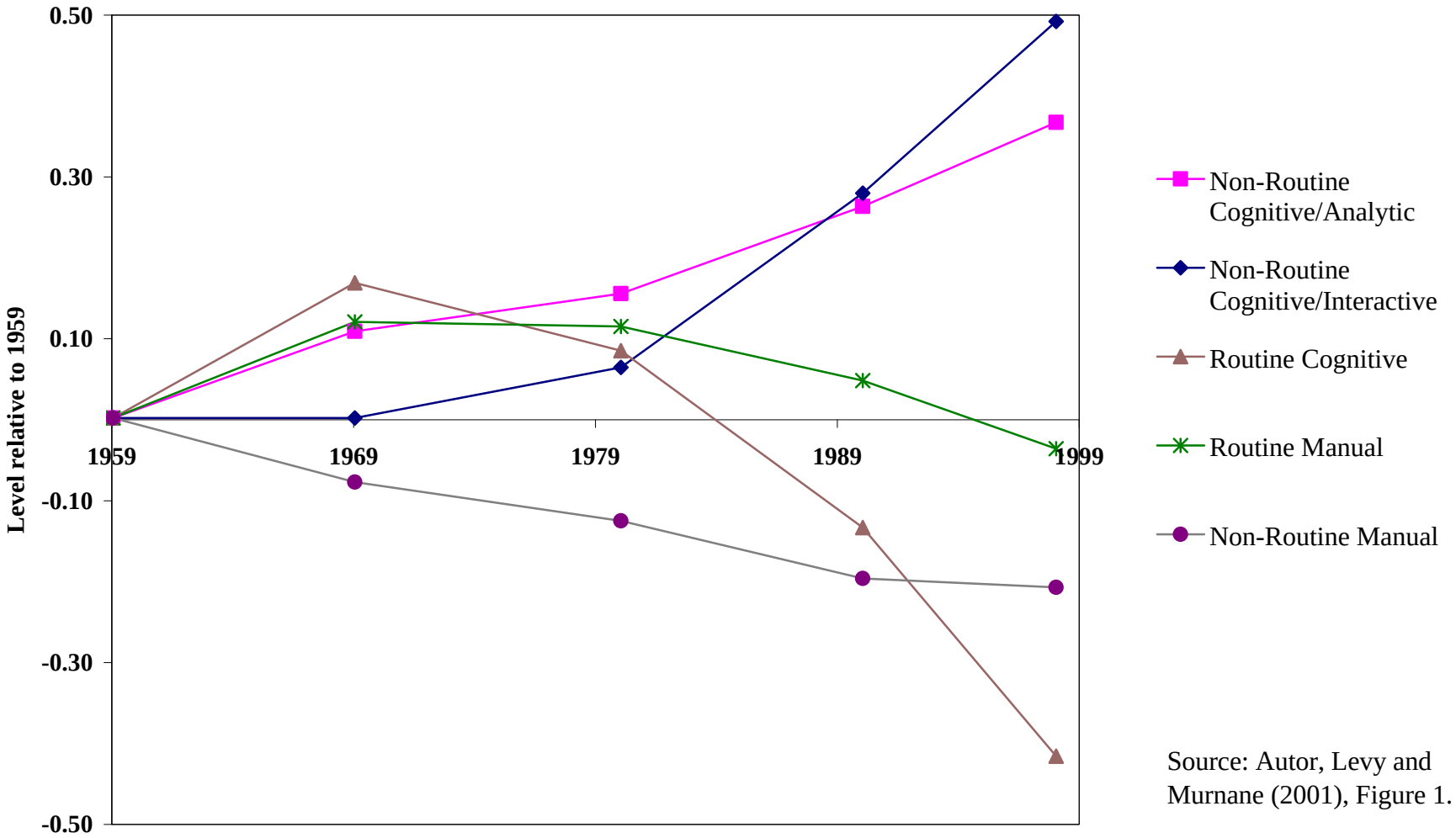

Source: Autor, Levy and Murnane (2001), Figure 1.

Linking Computerization to Skill Demands

More detailed investigation (Autor, Levy, Murnane 2001):

- Industries rapidly computerizing in 70s, 80s, 90s reduced demand for *routine* manual & cognitive tasks, increased demand for *non-routine* cognitive tasks.
- Parallel tasks shifts within:

  a) Detailed industries.

  b) Detailed occupations.

  c) Education groups within industries.
- Translating computer-induced task shifts into educational demands:
  - Shifts explain ~40% of acceleration since 1960, largest impact after 1980.
- Changes in tasks within nominally identical occupations explain more than half of demand shift induced by computerization.

Conclusion

1. Did computerization raise earnings inequality after 1980? *Only in part.*
   - Secularly rising demand for college educated workers since at least 1940s.
   - Dramatic supply changes: college 'boom' in the 1970s, 'bust' in the 1980s.
2. Best evidence: Demand shifts favoring college grads did *accelerate* in 1970s and/or 1980s.
3. How did computerization contribute to acceleration?
   - Displacing routine cognitive & manual tasks typically performed by High School Grads
   - Increasing demand for non-routine cognitive tasks typically performed by College Grads.