Skills vs. Tasks: How Important Are Occupations? *Complex-Task Biased Technological Change and the Labor Market by Colin Caines, Florian Hoffmann, and Gueorgui Kambourov (2016)*

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Econ 350, Winter 2023

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Complex-Task Biased Technological Change and the Labor Market

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Working Paper

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1. Introduction

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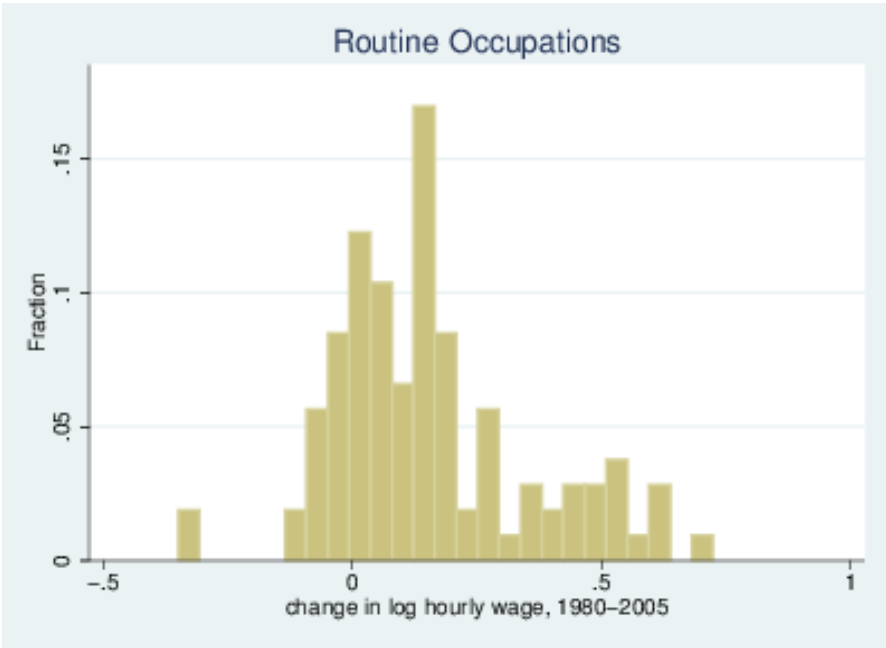
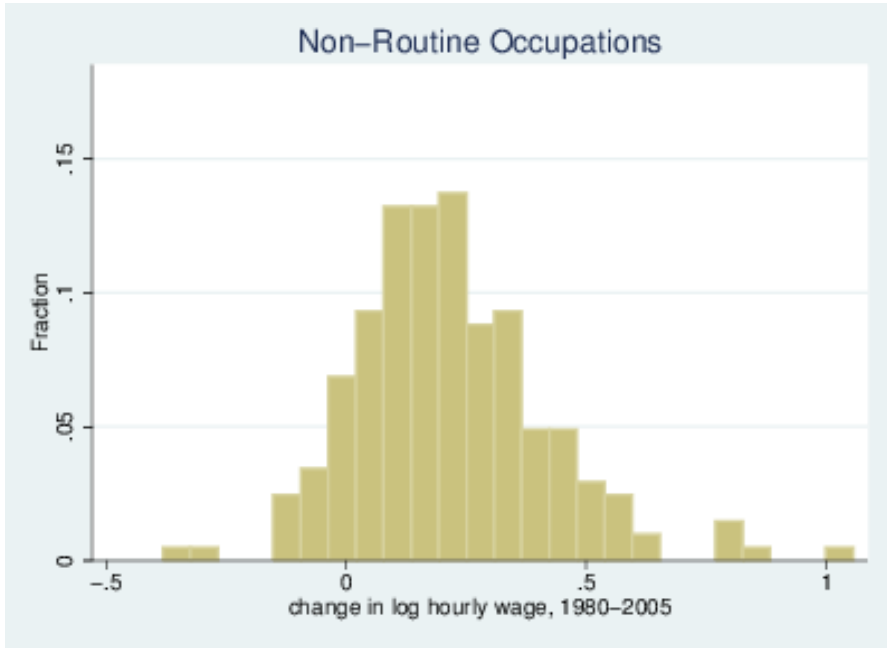
- Recent evidence that occupations which formerly offered middle-class and middle-skill jobs have lost ground in terms of wage and employment relative to both low- and high wage jobs.
- A popular explanation for this finding, quickly replacing the SBTC hypothesis as the primary theoretical economic framework for studying trends in wage inequality, is routine-biased technological change (RBTC).

Figure 1: Distribution of Hourly Wage Growth for Routine and Non-Routine Occupations





Notes: Data taken from the 1980 5% Sample of the US Census and the 2005 American Community Survey (ACS). Hourly wages constructed from total wage and salary data (adjusted using PCE deflator), number of weeks worked per year, and usual number of hours worked per year. Data is defined on the 3-digit occupation level. Routine occupations defined as in Autor and Dorn (2013), all other occupations defined as non-routine.

2. Task Complexity of Occupations

2.1 Wage and Employment Data

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- We compute data on the occupational wage and employment structure over time from the 1980 Census Integrated Public Use Microdata and the 2005 American Community Survey (ACS), imposing similar sample restrictions to Autor and Dorn (2013).
- Working sample consists of non-farm workers in the mainland United States between the ages of 16 and 64 (inclusive).
- The main part of our empirical analysis focuses on males.
- We also omit from our sample individuals who are institutionalized.
- Wage data refers to hourly wages, constructed from the census data for total wage and salary income (adjusted using the PCE deflator), number of weeks worked per year, and usual number of hours worked per week.

2.2 Classifying Occupations by Complexity

- Two sources of data are commonly used for quantifying the task content of occupations, the Dictionary of Occupational Titles (DOT) and its successor the Occupational Information Network (O*NET) production database.
- The O*NET has the advantage of offering a much broader set of occupational descriptors, which allows for a more precise measurement of task complexity.
- Furthermore, task measures are derived from a survey of incumbent workers rather than occupational analysts, as is the case for the DOT.
- We therefore rely on O*NET data in this paper (O*NET 20.1, October 2015). The O*NET is a publicly available dataset sponsored by the US Department of Labor.
- It compiles information on standardized measurable characteristics of occupations, referred to as descriptors.

- In total it contains 277 occupational descriptors sorted into 6 broad categories.
- These include the activities/tasks involved in working in an occupation, the requirements and qualifications needed to work in an occupation, as well as the knowledge/interests of the typical worker in an occupation.
- In selecting the relevant descriptors and mapping them into a unidimensional measure of task complexity using a principal components analysis we closely follow Yamaguchi (2012), although our selection of descriptors is much broader.
- To be more precise we first identify 35 O*NET descriptors that relate to our definition of task complexity.

- These descriptors are drawn from three subsections of the O*NET: "Abilities" (contained in "Worker Characteristics"), "Skills" (contained in "Worker Requirements"), and "Generalized Work Activities" (contained in "Occupational Requirements").
- Examples are "originality" and "inductive reasoning" from the abilities module, "complex problem solving" and "critical thinking" from the skills module, and "analyzing data or information" and "thinking creatively" from the activities module.
- The selected descriptors are evaluated with a consistent 0-7 scale that indicates the degree to which they are required to perform in a given occupation.
- In our view each of these is positively correlated with task complexity.

- As a second step we map the information contained in our selected occupational descriptors into a single dimension complexity score, converted to percentile rankings, via principal components analysis (PCA).

- The top 10 percent of occupations rated in the complexity ranking largely comprise professional, scientific/medical, and senior management occupations.

Table 1: Wages and Employment

	$\log(\text{wage}_{1980})$	$\log(\text{wage}_{2005})$	$\Delta\log(\text{wage})$	Employment Share		% Employment Change
				1980	2005	
simple	1.950	2.063	0.113	0.654	0.595	-0.090
complex	2.304	2.663	0.359	0.346	0.405	0.169

Notes: Wage and employment data taken from 1980 5% sample of the US Census and the 2005 ACS. Sample restricted to non-institutionalized males aged 16-64 in the mainland United States. Complex occupations defined as those whose complexity index is above the 66th percentile in the occupation-level complexity distribution. All other occupations are defined as simple. Also note that the table shows the percentage change in the employment shares of simple and complex occupations, not the change in the employment share. The latter sum to zero.

2.3 Routine Intensity and its Relation to Task Complexity

- The "routineness" of occupations has been intensively studied by the literature.

Table 2: Comparison of Complexity and Routinization

Routinizable Occupations with High Complex Content

Occupation Title	Routine Index Percentile	Complexity Index Percentile
Financial Managers	82.832	96.107
Real Estate Sales Occupations	87.421	66.059
Accountants & Auditors	95.505	80.246
Insurance Underwriters	95.978	66.272
Statistical Clerks	93.664	93.187
Clinical Laboratory Technologist & Technicians	74.926	72.267
Other Financial Specialists	77.206	75.284

Notes: The table reports values of the routine and complexity indices for a selection of occupations. The index values are converted to percentiles of the occupation-level distribution. See sections 2.2 and 2.3 for construction of routine index and complexity index.

Table 2: Comparison of Complexity and Routinization, Cont.

Non-Routinizable Occupations with Low Complex Content

Occupation Title	Routine Index Percentile	Complexity Index Percentile
Waiters & Waitresses	12.041	3.624
Baggage Porters, Bellhops and Concierges	9.360	27.510
Recreation Facility Attendants	27.039	12.234
Taxi Cab Drivers & Chauffeurs	5.055	28.072
Personal Service Occupations	26.628	30.089
Door-to-door Sales, Street Sales, and News Vendors	26.858	6.423
Bus Drivers	3.777	12.119

Notes: The table reports values of the routine and complexity indices for a selection of occupations. The index values are converted to percentiles of the occupation-level distribution. See sections 2.2 and 2.3 for construction of routine index and complexity index.

Table 3: Complexity, Routineness, Wages, and Employment

		$\log(\text{wage}_{1980})$	$\log(\text{wage}_{2005})$	$\Delta\log(\text{wage})$	Employment Share		% Employment Change
					1980	2005	
simple	routine	1.925	2.041	0.116	0.187	0.169	-0.098
	non-routine	1.959	2.071	0.112	0.466	0.426	-0.086
complex		2.304	2.663	0.359	0.346	0.405	0.169

Notes: Wage and employment data taken from 1980 5% sample of the US Census and the 2005 ACS. Sample restricted to non-institutionalized males aged 16-64 in the mainland United States. Complex occupations defined as those whose complexity index is above the 66th percentile in the occupation-level complexity distribution. All other occupations are defined as simple.

- We compute the routine task intensity index developed in Autor and Dorn (2013) as follows:

$$\text{Routine Task Intensity}_o = \ln(\text{Routine}_o) - \ln(\text{Manual}_o) - \ln(\text{Abstract}_o) \quad (1)$$

1. Wage levels and wage growth are higher in complex occupations than in simple occupations;
2. Within the simple occupations, wage levels as well as wage growth are the same for routine occupations and non-routine occupations;
3. There is reallocation from simple occupations to complex occupations over time;
4. Within the simple occupations, the routine occupations experienced a larger percent decline in employment over time than the non-routine occupations.

3. Empirical Analysis

3.1 Task Content of Occupations and Wage Levels

Table 4: Individual-Level Wage Regression, 1980 and 2005

Dependent Variable: Log Wages		
Independent Variable	1980	2005
Complexity Index	0.351***	0.711***
	(7.12)	(14.12)
Routine Index	-0.0128	0.0172
	(-0.29)	(0.33)
N	3987067	949585

Notes: The regressions include fixed effects for age (4 categories: 16-28, 29-40, 41-52, 53-64), education level (less than high school, high school, some college, college), and race (white, nonwhite). Standard errors clustered at occupation level.
t-statistics are in parentheses.
*p ¡ 0:1 ; **p ¡ 0:05 ; ***p ¡ 0:01.

3.2 Task Content of Occupations, Wage Growth, and Employment Growth

Table 5: Occupation-Level Wage Regression with Occupational Demographic Controls

	(A) Dependent Variable: Log Wages in 1980				(B) Dependent Variable: Log Wages in 2005			
	Complexity Variable: Complexity Index		Complexity Variable: Complex Indicator†		Complexity Variable: Complexity Index		Complexity Variable: Complex Indicator†	
Indep. Variable	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
Complexity Variable	0.102*	0.106*	0.00215	0.0233	0.400***	0.416***	0.115***	0.0863**
	(1.70)	(1.74)	(0.08)	(0.78)	(5.31)	(5.45)	(3.29)	(2.19)
Routine Index		0.0135	0.00476	0.00879		0.0512	0.0394	0.0317
		(0.42)	(0.15)	(0.27)		(1.28)	(0.95)	(0.76)
Female Share	-0.142***	-0.146***	-0.154***	-0.155***	-0.128**	-0.143***	-0.158***	-0.174***
	(-3.51)	(-3.51)	(-3.68)	(-3.71)	(-2.52)	(-2.75)	(-2.97)	(-3.24)
College Share	0.259***	0.265***	0.325***	0.295***	0.531***	0.554***	0.715***	0.676***
	(3.49)	(3.50)	(4.64)	(3.74)	(5.72)	(5.87)	(8.02)	(6.62)
High School Share	0.427***	0.423***	0.468***	0.478***	0.358**	0.342**	0.438***	0.565***
	(3.50)	(3.45)	(3.83)	(3.97)	(2.33)	(2.22)	(2.79)	(3.63)

Table 5: Occupation-Level Wage Regression with Occupational Demographic Controls, Cont.

	(A) Dependent Variable: Log Wages in 1980				(B) Dependent Variable: Log Wages in 2005			
	Complexity Variable: Complexity Index		Complexity Variable: Complex Indicator†		Complexity Variable: Complexity Index		Complexity Variable: Complex Indicator†	
Indep. Variable	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
Non-white	-0.279	-0.278	-0.264	-0.274	-0.170	-0.162	-0.0897	-0.137
Share	(-1.36)	(-1.35)	(-1.28)	(-1.32)	(-0.67)	(-0.63)	(-0.34)	(-0.51)
Married	0.889***	0.873***	0.943***	0.928***	0.574*	0.516	0.708**	0.725**
Share	(3.50)	(3.39)	(3.68)	(3.62)	(1.81)	(1.61)	(2.17)	(2.20)
Mean	0.00847**	0.00853**	0.00837**	0.00846**	0.0103**	0.0105**	0.00820	0.00989*
Age	(2.16)	(2.17)	(2.11)	(2.14)	(2.08)	(2.12)	(1.60)	(1.91)
Mean #	-0.0734	-0.0666	-0.0687	-0.0723	0.0415	0.0667	0.0761	0.0550
Children	(-0.66)	(-0.59)	(-0.61)	(-0.64)	(0.30)	(0.47)	(0.52)	(0.37)
N	315	315	315	315	310	310	310	310

Group-Level Estimation

Table 6: Group-Level Employment Growth Regression

Dependent Variable: Change in Employment Share 1980-2005			
Independent Variable	(i)	(ii)	(iii)
Complexity Index	0.0000314***	0.0000226**	0.0000245**
	(3.07)	(2.30)	(2.38)
Routine Index		-0.0000247*	-0.0000252**
		(-1.94)	(-1.98)
Order of Wage Poly.	0	0	3
$N = 15177$			

Notes: The table reports results when occupation-level data is disaggregated to occupation x gender x education x race x age cells (see section 3.2 for discussion). Regressions include gender x education x race x age fixed effects. Standard errors clustered at the occupation level. *t*-statistics are in parentheses. Significance levels are: ***1% , **5%, *10%.

- Table 6 shows the results from the group-level regressions for employment.

Table 7: Occupation-Level Wage Growth Regression with Occupational Demographic Means

Dependent Variable: Change in Log Wages 1980-2005					
Independent Variable	Complexity Variable: Complexity Index			Complexity Variable: Complex Indicator†	
	(i)	(ii)	(iii)	(iv)	(v)
Complexity Variable	0.304***	0.316***	0.347***	0.138***	0.0685**
	(4.94)	(5.07)	(5.74)	(5.02)	(2.19)
Routine Index		0.0394	0.0333	0.0260	0.0158
		(1.20)	(1.04)	(0.81)	(0.47)
Female Share	0.00628	-0.00519	-0.0293	-0.0263	-0.0498
	(0.15)	(-0.12)	(-0.70)	(-0.62)	(-1.14)
College Share	0.271***	0.288***	0.288***	0.350***	0.382***
	(3.57)	(3.74)	(3.53)	(4.39)	(4.36)
High School Share	-0.104	-0.116	0.0613	0.117	0.233*
	(-0.83)	(-0.93)	(0.48)	(0.92)	(1.79)

Table 8: Occupation-Level Wage Growth Regression with Occupational Demographic Means, Cont.

Dependent Variable: Change in Log Wages 1980-2005					
Independent Variable	Complexity Variable: Complexity Index			Complexity Variable: Complex Indicator†	
	(i)	(ii)	(iii)	(iv)	(v)
Non-white Share	0.103	0.109	0.0153	0.0965	0.0522
	(0.49)	(0.52)	(0.08)	(0.47)	(0.25)
Married Share	-0.244	-0.289	0.0573	0.234	0.213
	(-0.94)	(-1.11)	(0.22)	(0.88)	(0.77)
Mean Age	0.00201	0.00216	0.00358	0.000574	0.00267
	(0.49)	(0.53)	(0.88)	(0.14)	(0.63)
Mean # Children	0.0557	0.0751	0.00406	-0.0202	-0.00622
	(0.48)	(0.65)	(0.04)	(-0.17)	(-0.05)
Order of Wage Poly.	0	0	3	3	3
$N = 310$					

Table 9: Occupation-Level Employment Growth Regression with Occupational Demographic Means

Dependent Variable: Change in Log Wages 1980-2005					
Independent Variable	Complexity Variable: Complexity Index			Complexity Variable: Complex Indicator†	
	(i)	(ii)	(iii)	(iv)	(v)
Complexity Variable	0.304***	0.316***	0.347***	0.138***	0.0685**
	(4.94)	(5.07)	(5.74)	(5.02)	(2.19)
Routine Index		0.0394	0.0333	0.0260	0.0158
		(1.20)	(1.04)	(0.81)	(0.47)
Female Share	0.00628	-0.00519	-0.0293	-0.0263	-0.0498
	(0.15)	(-0.12)	(-0.70)	(-0.62)	(-1.14)
College Share	0.271***	0.288***	0.288***	0.350***	0.382***
	(3.57)	(3.74)	(3.53)	(4.39)	(4.36)
High School Share	-0.104	-0.116	0.0613	0.117	0.233*
	(-0.83)	(-0.93)	(0.48)	(0.92)	(1.79)

Table 9: Occupation-Level Employment Growth Regression with Occupational Demographic Means, Cont.

Dependent Variable: Change in Log Wages 1980-2005					
Independent Variable	Complexity Variable: Complexity Index (i)	(ii)	(iii)	Complexity Variable: Complex Indicator† (iv)	(v)
Non-white Share	0.103	0.109	0.0153	0.0965	0.0522
	(0.49)	(0.52)	(0.08)	(0.47)	(0.25)
Married Share	-0.244	-0.289	0.0573	0.234	0.213
	(-0.94)	(-1.11)	(0.22)	(0.88)	(0.77)
Mean Age	0.00201	0.00216	0.00358	0.000574	0.00267
	(0.49)	(0.53)	(0.88)	(0.14)	(0.63)
Mean # Children	0.0557	0.0751	0.00406	-0.0202	-0.00622
	(0.48)	(0.65)	(0.04)	(-0.17)	(-0.05)
Order of Wage Poly.	0	0	3	3	3
$N = 310$					

Table 10: Group-Level Wage Growth Regression

Dependent Variable: Change in Log Wages 1980-2005			
Independent Variable	(i)	(ii)	(iii)
Complexity Index	0.258***	0.274***	0.349***
	(10.99)	(10.02)	(12.60)
Routine Index		0.0445	0.0458
		(1.42)	(1.55)
Order of Wage Poly.	0	0	3
$N = 15177$			

Notes: The table reports results when occupation-level data is disaggregated to occupation x gender x education x race x age cells (see section 3.2) for discussion. Regressions include gender x education x race x age fixed effects. Standard errors clustered at the occupation level. t-statistics are in parentheses. Significance levels are: ***1% , **5%, *10%.

3.3 Robustness

Table 11: Occupation-Level Wage Growth Regression by 1980 Wage Tercile

Dependent Variable: Change in Log Wages 1980-2005			
Independent Variable	First Tercile (i)	Second Tercile (ii)	Third Tercile (iii)
Complexity Index	0.553***	0.489***	0.626***
	(8.35)	(7.91)	(5.44)
Routine Index	-0.0327	-0.0410	0.131*
	(-0.70)	(-0.88)	(1.90)
Order of Wage Poly.	3	3	3
N	112	108	90

Notes: The table reports results for occupation-level regressions run for different terciles of the 1980 occupational wage distribution. t-statistics are in parentheses. Significance levels are: ***1% , **5%, *10%.

4. Theoretical Framework

4.1 Overview

- Four robust empirical facts about the evolution of the occupational wage and employment structure.
- These are:
  - (i) wages, measured either in growth or in levels, are not significantly related to routine-task intensity once one conditions on task complexity;
  - (ii) task complexity is strongly positively related to wage levels and wage growth;
  - (iii) there has been a reallocation of labor from simple to complex occupations, and this employment growth effect is weaker than the growth in the complexity wage premium;
  - (iv) within the simple occupations, the share of non-routine occupations has increased.

4.2 The Model

- Closed economy in which a final good Y is produced using three intermediate production processes.
- Output from the three processes, defined by the tasks that need to be performed, is $(y_c; y_R; y_{NR})$, where s stands for "simple",
- c stands for "complex", R stands for "routine" and NR stands for "non-routine".
- The mapping from intermediate to final output is given by the function

$$Y = F_Y(y_c; y_R; y_{NR}).$$

- Impose the following functional form restrictions:

$$F_Y = (y_s)^{\gamma} \cdot (y_c)^{1-\gamma}; \gamma = .5 \tag{2}$$
$$y_s = [(y_R)^{\mu} + (y_{NR})^{\mu}]^{\frac{1}{\mu}}.$$

- Output can be used either for producing capital, with technology

$$K = \left(\frac{1}{\pi_K}\right) \cdot Y, \tag{3}$$

$$y_c = (\alpha_c \cdot C)^{\rho} \cdot (\alpha_{k,c} \cdot K_c)^{1-\rho} \tag{4}$$

$$y_R = [\alpha_{s,R} \cdot S_R^{\psi} + \alpha_{k,R} \cdot K_R^{\psi}]^{\frac{1}{\psi}}$$

$$y_{NR} = \alpha_{s,NR} \cdot S_{NR}.$$

$$G(c) = 1 - \left(\frac{c_m}{c}\right)^{\beta}. \tag{5}$$

Proposition.

- Consider two stationary state equilibrium allocations of labor together with their factor prices, $(C^0, S_R^0, S_{NR}^0, w_c^0, w_R^0, w_{NR}^0)$ and $(C^1, S_R^1, S_{NR}^1, w_c^1, w_R^1, w_{NR}^1)$.
- Assume that $\psi > \mu > \mu*$.
- Then an increase in the factor productivity of the labor input, α_c (or of the capital input,$\alpha_{k,c}$) in the complex technology, has the following effect on the equilibrium allocations and factor prices

$$
\begin{aligned}
C^1 &> C^0 \\
S_R^1 &< S_R^0 \\
S_{NR}^1 &< S_{NR}^0 \\
\frac{S_{NR}^1}{S_R^1} &> \frac{S_{NR}^0}{S_R^0} \\
w_R^0 &= w_{NR}^0 \\
w_R^1 &= w_{NR}^1 \\
\frac{w_c^1}{w_{NR}^1} &> \frac{w_c^0}{w_{NR}^0}
\end{aligned}
\tag{6}
$$

□

4.3 Discussion

- For $\frac{S_{NR}}{S_R+S_{NR}}$ to increase while S_{NR} decreases, μ can neither be too small nor too large. Indeed, if it was too small, S_{NR} would increase rather than decrease.
- If it was too large, then S_{NR} would decrease even faster than S_R. This explains the condition on the structural parameters in the proposition.
- An interesting result not mentioned in the proposition is that the model is consistent with a situation in which the relative wage $(\frac{w_C}{w_R})$ increases dramatically whereas the equilibrium employment share of the complex occupations C^* raises only slightly.
- This can be seen from the following equation, derived in Appendix C, together with equation (B.1)

$$C^* = \left(\frac{\beta}{\beta - 1}\right) \cdot c_m^{\beta} \cdot \left(\frac{w_C}{w_R}\right)^{\beta-1}. \tag{7}$$

5. Complexity and Social Skills

Table 12: Comparison of Complexity and Social Skills

Occupations with High Complex Content and Low Social Skill Content

Occupation Title	Social Skill Percentile	Complexity Index Percentile
Computer and Peripheral Equipment Operators	48.487	73.739
Aircraft Mechanics	49.101	75.482
Programmers of Numerically Controlled Machine Tools	49.114	67.755
Power Plant Operators	49.637	67.861
Mathematicians and Statisticians	0.772	91.498
Biological Technicians	46.720	73.276

Notes: The table reports values of the social skill and complexity indices for a selection of occupations. The index values are converted to percentiles of the occupation-level distribution. See sections 2.2 and 5 for the construction of the complexity and the social skill indices.

Table 12: Comparison of Complexity and Social Skills, Cont.

Occupations with Low Complex Content and High Social Skill Content

Occupation Title	Social Skill Percentile	Complexity Index Percentile
Retail Salespersons & Sales Clerks	62.216	49.932
Door-to-door Sales, Street Sales, and New Vendors	68.324	6.423
Bill and Account Collectors	70.030	45.091
Supervisors of Clearning and Building Services	62.950	33.389
Eligibility Clerk for Government Programs	56.031	49.939
Sheriffs, Bailiffs, Correctional Institution Officers	56.278	43.805

Notes: The table reports values of the social skill and complexity indices for a selection of occupations. The index values are converted to percentiles of the occupation-level distribution. See sections 2.2 and 5 for the construction of the complexity and the social skill indices.

Table 13: Complexity, Social Skills, Wages, and Employment

		$\log(\text{wage}_{1980})$	$\log(\text{wage}_{2005})$	$\Delta\log(\text{wage})$	Employment Share		% Employment Change
					1980	2005	
simple	nonsocial	1.924	2.028	0.104	0.598	0.558	-0.068
	social	2.220	2.430	0.210	0.055	0.037	-0.326
complex	nonsocial	2.250	2.559	0.309	0.056	0.077	0.379
	social	2.314	2.681	0.367	0.291	0.328	0.129

Notes: Wage and employment data is taken from the 1980 5% sample of the US Census and the 2005 ACS. The sample is restricted to non-institutionalized males aged 16-64 in the mainland United States. Complex occupations are defined as those whose complexity index is above the 66th percentile in the occupation-level complexity distribution. All other occupations are defined as simple. Social occupations are defined as those whose social skills index is above the 66th percentile in the occupation-level social skills distribution. All other occupations are defined as nonsocial.

Table 14: Wage Growth Regression with Social Skills

Dependent Variable: Change in Log Wages 1980-2005			
Independent Variable	(i)	(ii)	(iii)
Complexity Index	0.428***	0.277***	0.280***
	(6.63)	(3.82)	(4.57)
Routine Index	0.0314	0.0406	0.0505
	(1.02)	(1.26)	(1.65)
Social Skill	0.164***	0.110*	0.0740
	(2.65)	(1.73)	(1.42)
Controls	None	Occ Dem Means	Group Level
Order of Wage Poly.	3	3	3
N	310	310	15177