Explaining Job Polarization: Routine-Biased Technological Change and Offshoring

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1 Summary and Introduction

In this paper, they consider the pervasiveness of job polarization in 16 Western European countries over the period 1993–2010. They

- illustrate the pattern of job polarization in data,
- develop the economic model with "tasks",
- estimate parameters of the model, and
- evaluate changes of employment with estimated parameters.

The "Skill-Biased Technological Change" hypothesis (SBTC): the observation that the demand (e.g. labour demand) is shifting in favour of more educated workers, has exhibited a good fit to the actual data for decades. However, the pattern observed in the recent data, which is called "Job Polarization", cannot be explained by SBTC.

- Job polarization: decrease in the demand for middling occupations comparing to that for high-paying occupations and low-paying occupations.

They argue that this job polarization can be explained by the so-called "Routine-Biased Technological Change" (RBTC): technological change biased toward replacing labour in routine tasks.

This paper also highlights the importance of within-industry and between-industry components of job polarization; that is, in this paper they empirically examine

- within-industry job polarization: a shift away from routine occupations given employment structure of industries, and
- between-industry job polarization: RBTC induces less employment share of industries which is intense in middling occupations while the effect is attenuated by a shift in product demand toward these industries because of biased improvement in technology.

2 Data

This section briefly describes the data used in this paper and the patten of job polarization observed in the data.

This paper use datasets from following sources:

- the harmonized individual level European Union Labour Force Survey (ELFS) for the 17-year period 1993–2010 for employment status, work hour, and occupation codes, and
- the OECD STAN Database for Industrial Analysis for measures of industry output, industry marginal costs, and relative output prices.

As a measure of routineness and offshorebility, they employ certain measure recommended by Autor (2013), Routine Task Intensity (RTI), and one developed by Blinder and Krueger (2013), respectively.

Table 1—Levels and Changes in the Shares of Hours Worked, 1993–2010

Occupations ranked by mean European wage	ISCO code	Average employment share in 1993 (in percent) (1)	Percentage point change 1993–2010 (2)	RTI (3)	Offshor-ability (4)	Within (5)	Between (6)
High-paying occupations		31.67	5.62 > 0	−0.72	−0.12	3.11	2.51
Corporate managers	12	5.65	0.59	−0.75	−0.32	0.49	0.10
Physical, mathematical, and engineering professionals	21	2.93	1.36	−0.82	1.05	1.11	0.25
Life science and health professionals	22	2.01	0.57	−1.00	−0.76	0.23	0.34
Other professionals	24	2.79	1.38	−0.73	0.21	0.67	0.71
Managers of small enterprises	13	4.16	0.17	−1.52	−0.63	−0.03	0.19
Physical, mathematical, and engineering associate professionals	31	4.44	0.21	−0.40	−0.12	0.22	−0.01
Other associate professionals	34	7.24	0.79	−0.44	0.10	0.27	0.53
Life science and health associate professionals	32	2.45	0.55	−0.33	−0.75	0.14	0.41
Middling occupations		46.75	−9.27 < 0	0.69	0.24	−4.77	−4.50
Stationary plant and related operators	81	1.70	−0.25	0.32	1.59	0.06	−0.31
Metal, machinery, and related trade work	72	8.78	−2.08	0.46	−0.45	−0.81	−1.26
Drivers and mobile plant operators	83	5.03	−0.48	−1.50	−1.00	−0.11	−0.38
Office clerks	41	10.60	−2.06	2.24	0.40	−2.34	0.28
Precision, handicraft, craft printing, and related trade workers	73	1.45	−0.54	1.59	1.66	−0.30	−0.24
Extraction and building trades workers	71	7.35	−0.64	−0.19	−0.93	0.39	−1.03
Customer service clerks	42	2.13	0.06	1.41	−0.25	−0.14	0.20
Machine operators and assemblers	82	5.99	−1.63	0.49	2.35	−0.56	−1.07
Other craft and related trade workers	74	3.72	−1.66	1.24	1.15	−0.96	−0.69
Low-paying occupations		21.56	3.65 > 0	−0.08	−0.84	1.66	1.99
Laborers in mining, construction, manufacturing, and transport	93	4.26	−0.55	0.45	−0.66	0.01	−0.55
Personal and protective service workers	51	6.86	2.36	−0.60	−0.94	0.65	1.71
Models, salespersons, and demonstrators	52	6.06	−0.11	0.05	−0.89	0.29	−0.40
Sales and service elementary occupations	91	4.38	1.95	0.03	−0.81	0.72	1.23

Notes: Occupations are ordered by their mean wage across the 16 European countries across all years. Columns 1, 2, 5, and 6: all countries, long difference 1993–2010, employment pooled across countries. Columns 3 and 4: measures rescaled to mean 0 and standard deviation 1, a higher value means an occupation is more routine intense (column 3) or more offshorable (column 4). The RTI index in column 3 is based on the five original DOT task measures in Autor, Levy, and Murnane (2003) and is identical to the index used in Autor and Dorn (2013) and Autor, Dorn, and Hanson (2013). The offshorability measure in column 4 is taken from Blinder and Krueger (2013) and is based on professional coders' assessment of the ease with which an occupation could potentially be offshored. Columns 5 and 6: shiftshare analysis of occupational employment share changes, within and between industries.

TABLE 2—INITIAL SHARES OF HOURS WORKED AND PERCENTAGE CHANGES OVER 1993–2010 (*by Country*)

	Four lowest-paying occupations		Nine middling occupations		Eight highest-paying occupations	
	Employment share in 1993 (in percent)	Percentage point change 1993–2010	Employment share in 1993 (in percent)	Percentage point change 1993–2010	Employment share in 1993 (in percent)	Percentage point change 1993–2010
Austria	21.82	6.36	51.61	−10.44	26.57	4.08
Belgium	17.49	3.00	48.50	−12.07	34.01	9.08
Denmark	24.09	1.73	39.70	−10.30	36.21	8.56
Finland	20.24	−1.50	39.69	−10.60	40.06	12.10
France	19.92	4.19	46.69	−8.60	33.39	4.41
Germany	20.71	2.37	48.03	−6.74	31.26	4.37
Greece	21.66	4.81	47.81	−10.65	30.54	5.84
Ireland	21.13	3.68	48.21	−14.85	30.66	11.17
Italy	27.01	6.06	51.04	−10.59	21.94	4.53
Luxembourg	21.70	−2.38	49.91	−10.76	28.40	13.15
Netherlands	16.78	1.99	37.90	−7.56	45.33	5.57
Norway	22.85	4.73	38.82	−8.47	38.34	3.74
Portugal	25.75	0.73	47.46	−4.86	26.78	4.13
Spain	28.02	1.01	48.67	−11.95	23.30	10.93
Sweden	21.82	1.52	41.98	−9.55	36.20	8.03
United Kingdom	16.88	4.17	43.64	−10.94	39.49	6.77

Notes: Long difference 1993–2010. Occupational employment pooled within each country. Occupations are grouped according to the mean European occupational wage as in Table 1.

3 Model

This section focuses on how they model the economy so that they can

- understand job polarization, and
- relate the shift-share analysis to an economic model.

3.1 A Framework to Understand Job Polarization

Consider the canonical model with tasks; that is, in this model, a good Y_i in industry i is produced with CES production

$$Y_i(T_1, \ldots, T_J) = \left[\sum_{j=1}^{J} (\beta_{ij} T_{ij})^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \text{ with } \eta > 0, \tag{1}$$

where T_{ij} is the use of task j in industry i, η is the elasticity of substitution between tasks in goods production, and β_{ij} is the intensity of the use of task

j in industry i. Here, they consider, as inputs of good production, tasks such that

- there exist J kinds of tasks in the economy,
- task is produced by labour input N_{ij} and other inputs K_{ij} (such as computer and off-shoring):

$$T_{ij}(N_{ij}, K_{ij}) = N_{ij}^{\kappa} K_{ij}^{1-\kappa} \text{ with } 0 < \kappa < 1, \tag{2}$$

- each task contributes to good production differently,
- each task has a different factor price (e.g. wage for high-skilled and wage for low-skilled); therefore, each task has a different cost for its production.

Note that in the following, they assume task j is equivalent to occupation j.

Conditional on the industry-level output Y_i, they derive the demand for labour in each occupation j through cost-minimization for good production and the labour demand for task production conditional on task output (Goos, Manning, and Salomons 2010).

$$\begin{aligned} \log N_{ijct} = &- [(1-\kappa) + \kappa\eta] \log w_{jct} + +(1-\eta)(1-\kappa) \log r_{jct} \\ &+ \eta \log c_{ict}^{I} + \log Y_{ict} + (\eta - 1) \log \beta_{ij} + \varepsilon_{ijct}, \end{aligned} \tag{3}$$

where subscript c and t represent country and time, respectively, w_{jct} and r_{jct} are factor prices of labour and other input, and c_{ict}^{I} represents industry-level cost of (unit) good production. Assuming that only RBTC and off-shoring, which are measured by RIT R_j and offshorebility F_j, affect change in the price r_{jct} over time; that is,

$$\frac{\partial \log r_{jct}}{\partial t} = \gamma_R R_j + \gamma_F F_j, \tag{4}$$

we can replace $\log r_{jct}$ by

$$\log r_{jct} = (\gamma_R R_j + \gamma_F F_j) \times time \tag{5}$$

As a result, we obtain the first estimation equation:

$$\begin{aligned}\log N_{ijct} = &-[(1-\kappa)+\kappa\eta]\log w_{jct} + (1-\eta)(1-\kappa)(\gamma_R R_j + \gamma_F F_j) \\ &\times time + \eta \log c^I_{ict} + \log Y_{ict} + (\eta - 1)\log \beta_{ij} + \varepsilon_{ijct}.\end{aligned} \tag{6}$$

3.2 Explaining Job Polarization within and between Industries

So far, the labour demand conditional on industry-level output Y_i is considered. Then, in order to examine the effect of a demand shift among industries, they introduce demand-side information of goods:

$$\log Y_{ict} = -\varepsilon \log P_{ict} + \log Y_{ct} + \xi_{ict}, \tag{7}$$

where P_{ict} is the industry-country-year specific price indices available from STAN relative to a country-year aggregate price index, and Y_{ct} is a measure of aggregate income, and

$$\log P_{ict} = \log \mu + \log c^I_{ict} \text{ with } \mu > 1, \tag{8}$$

where μ is the price mark-up. Note that equation (7) and (8) are implied by the assumption of homothetic preference represented by CES utility function and monopolistic competition, respectively. With equation (7) and (8), they derive

$$\begin{aligned}\log N_{ijct} = &-[(1-\kappa)+\kappa\eta]\log w_{jct} + (1-\eta)(1-\kappa)(\gamma_R R_j + \gamma_F F_j) \times time \\ &+ (\eta - \varepsilon)\log c^I_{ict} + \log Y_{ct} - \varepsilon \log \mu + (\eta - 1)\log \beta_{ij} + \varepsilon_{ijct},\end{aligned} \tag{9}$$

which is used for the following shift-share analysis.

- The shift-share analysis is the analysis that decompose the share of occupation in total employment into the share of occupation in total employment of each industry and the share of employment in each industry in total employment.

Formally, in a standard shift-share analysis, the share of occupation j in total employment at time t, s_{jt}, can be written as

$$s_{jt} = \sum_{i=1}^{I} \tau_{it} s_{j|it}, \tag{10}$$

where $s_{j|it}$ is the share of occupation j in total employment of industry i at time t, and τ_{it} is the share of employment in industry i in total employment at time t. To relate this expression to the economic model in the previous section, they differentiate equation (10):

$$\frac{\partial s_{jt}}{\partial t} = \sum_{i=1}^{I} \tau_{it} s_{j|it} \left[\frac{\partial \log s_{j|it}}{\partial t} + \frac{\partial \log \tau_{it}}{\partial t} \right] \tag{11}$$

With equation (9), we can write down the first term, within-industry component, and the second term, between-industry component, as follows:

$$\begin{aligned} \frac{\partial s_{jt}}{\partial t} &= s_{jt}(1-\eta)(1-\kappa)\gamma_R \\ &\times \left\{ \left(R_j - \sum_{i=1}^{I} s_{j|it} R_{it}^I \right) + \frac{1-\varepsilon}{1+\eta} \sum_{i=1}^{I} s_{j|it} (R_{it}^I - R_t^{agg}) \right\} \end{aligned} \tag{12}$$

Note that as shown in the next section, the coefficient of R_j in equation (6) $(1-\eta)(1-\kappa)\gamma_R$ is estimated to be negative.

As to within-industry component,

- $R_{it}^I = \sum_{j=1}^{J} s_{j|it} R_j$: the (weighted) average level of routineness across occupations in industry i at time t,

- $\left(R_j - \sum_{i=1}^{I} s_{j|it} R_{it}^{I}\right) = \sum_{i=1}^{I} s_{j|it}\left(R_j - R_{it}^{I}\right)$: the difference between routineness of occupation j and overall average routineness at time t.

Within each industry, consider the difference between routineness of occupation j and average routineness. Then, sum up these differences weighted by occupation share of j in each industry. For instance, suppose that in every industry in which occupation j is used, R_j is high relative to all other occupations. Then, a large shift away from occupation j within each of those industries should be expected.

As to between-industry component,

- R_t^{agg}: the average level of routineness of the economy.

- $\frac{1}{1+\eta}\sum_{i=1}^{I} s_{j|it}(R_{it}^{I} - R_t^{agg})$: a shift of the labour demand conditional on given levels of industry outputs. e.g. with RBTC, the labour demand should be concentrated on industries that is less intense in routine tasks to produce fixed amount of industry outputs because industries intense in routine tasks require less labour input for production.

- $\frac{-\varepsilon}{1+\eta}\sum_{i=1}^{I} s_{j|it}(R_{it}^{I} - R_t^{agg})$: a shift of the labour demand in response to change in relative output prices. e.g. because of technological improvement in routine-intensive industries, goods of these industries become cheaper, which induces an increase in the demand of their goods and, therefore, an increase in the labour demand.

As long as we assume $\varepsilon > 0$, the effect represented by the second term should offset the effect represented by the first term but should not overturn it unless $\varepsilon > 1$, which is not the case according to the paper ($\varepsilon = 0.42$).

4 Empirical Results

This section describes the estimation result of structural coefficients and the shift-share analysis. Table 3 shows the estimation result of equation (6):

$$\log N_{ijct} = -\left[(1-\kappa)+\kappa\eta\right]\log w_{jct} + (1-\eta)(1-\kappa)(\gamma_R R_j + \gamma_F F_j) \\ \times\, time + \eta \log c^I_{ict} + \log Y_{ict} + (\eta - 1)\log \beta_{ij} + \varepsilon_{ijct}.$$

TABLE 3—ESTIMATING LABOR DEMAND DEPENDENT VARIABLE: LOG (*Hours worked*/1,000)

Linear time-trend interacted with:	(1)	(2)	(3)	(4)	(5)
RTI	−0.900***	−0.888***	−0.866***	−0.868***	
	(0.126)	(0.135)	(0.141)	(0.129)	—
Offshorability	−0.013	−0.005	−0.006		−0.383**
	(0.159)	(0.175)	(0.180)	—	(0.165)
log industry marginal costs		0.854***	0.895***	0.895***	0.899***
	—	(0.145)	(0.161)	(0.161)	(0.161)
log industry output		0.142**	1	1	1
	—	(0.061)			
Observations	48,139	44,062	44,062	44,062	44,062
R^2	0.954	0.947			

Notes: Point estimates (and standard errors in parentheses) on RTI and offshorability have been multiplied by 100. All regressions include occupation-industry-country fixed effects. The regression in column 1 contains industry-country-year fixed effects and regressions in columns 2–5 contain year fixed effects. Standard errors are clustered by occupation-industry-country.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Table 3 shows that routineness has a negative effect on the labour demand while offshorebility does not have any effect. Table 4 shows the calculation result of equation (12):

$$\frac{\partial s_{jt}}{\partial t} = s_{jt}(1-\eta)(1-\kappa)\gamma_R \times \left\{ \left(R_j - \sum_{i=1}^{I} s_{j|it} R^I_{it} \right) + \frac{1-\varepsilon}{1+\eta} \sum_{i=1}^{I} s_{j|it}(R^I_{it} - R^{agg}_t) \right\}$$

Table 4—Actual and Predicted Percentage Point Changes in the Shares of Hours Worked, 1993–2010

Occupations ranked by mean European wage	ISCO code	Actual changes: Total (1)	Actual changes: Within (2)	Actual changes: Between (3)	Predicted changes: Total (4)	Predicted changes: Within (5)	Predicted changes: Between (6)
High-paying occupations		5.62	3.11	2.51	4.45	3.56	0.90
Corporate managers	12	0.59	0.49	0.10	0.51	0.73	−0.22
Physical, mathematical, and engineering professionals	21	1.36	1.11	0.25	0.20	0.42	−0.22
Life science and health professionals	22	0.57	0.23	0.34	0.78	0.22	0.56
Other professionals	24	1.38	0.67	0.71	0.44	0.31	0.13
Managers of small enterprises	13	0.17	−0.03	0.19	1.33	0.91	0.42
Physical, mathematical, and engineering associate professionals	31	0.21	0.22	−0.01	0.13	0.35	−0.22
Other associate professionals	34	0.79	0.27	0.53	0.38	0.59	−0.21
Life science and health associate professionals	32	0.55	0.14	0.41	0.69	0.03	0.66
Middling occupations		−9.27	−4.77	−4.50	−6.86	−3.65	−3.21
Stationary plant and related operators	81	−0.25	0.06	−0.31	−0.36	0.00	−0.36
Metal, machinery, and related trade work	72	−2.08	−0.81	−1.26	−1.33	−0.30	−1.03
Drivers and mobile plant operators	83	−0.48	−0.11	−0.38	1.33	1.13	0.20
Office clerks	41	−2.06	−2.34	0.28	−3.63	−3.33	−0.30
Precision, handicraft, craft printing, and related trade workers	73	−0.54	−0.30	−0.24	−0.55	−0.27	−0.28
Extraction and building trades workers	71	−0.64	0.39	−1.03	0.74	0.19	0.54
Customer service clerks	42	0.06	−0.14	0.20	−0.52	−0.39	−0.13
Machine operators and assemblers	82	−1.63	−0.56	−1.07	−1.32	−0.17	−1.15
Other craft and related trade workers	74	−1.66	−0.96	−0.69	−1.22	−0.51	−0.71
Low-paying occupations		3.65	1.66	1.99	2.41	0.10	2.31
Laborers in mining, construction, manufacturing, and transport	93	−0.55	0.01	−0.55	−0.39	−0.19	−0.20
Personal and protective service workers	51	2.36	0.65	1.71	2.33	0.32	2.01
Models, salespersons, and demonstrators	52	−0.11	0.29	−0.40	0.03	0.03	0.00
Sales and service elementary occupations	91	1.95	0.72	1.23	0.44	−0.06	0.50

$\frac{4.45}{5.62} = 79\%$

$\frac{6.86}{9.27} = 74\%$

$\frac{2.41}{3.65} = 66\%$

Notes: Occupations are ordered by their mean wage across the 16 European countries across all years. Employment pooled across countries; long difference over 1993–2010. Predicted changes are constructed from equation (13) using an estimate of 0.42 for the elasticity of product demand together with point estimates in column 3 of Table 3 accounting for the simultaneous impacts of RBTC as well as offshoring.