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Employment Polarization in Germany: Role of Technology, Trade and Human Capital

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Abstract

State-of-the-art: Over the last two decades, United States and Great Britain have experienced a tremendous increase in the share of employment in occupations with high-level and low-level skill requirements, and disappearance of occupations requiring medium-level skill requirements. This phenomenon of employment â??polarizationâ?• has been coupled with a significant rise in income inequality, with the share of employment being concentrated in the highest and lowest income occupations. The most prominent explanations for such polarization effects provided in the literature (Autor et al. 2003, 2013a, 2013b; Spitz-Oener 2006; Senftleben and Wielandt 2013, Rendall and Weiss 2014) are technology shock such as increase in automation, information and communications technology (ICT) and globalization such as off-shoring and outsourcing.

Research gap: While empirical evidence on the effects of international trade and computerization on employment and wage patterns is extensive, it is limited to explaining these changes with respect to age, educational background, gender, skill levels, occupations and employment status of workers. Furthermore, the extent to which trade and technology overlap in shaping sectoral and regional employment patterns remains significantly under-researched. Addressing this caveat of existing research, the current paper attempts to focus on apprenticeship training and works councils as additional dimensions for explaining regional differences in employment changes in Germany.

Theoretical arguments: Local regions in Germany vary extensively not only in administrative and political attributes but also in several socio-economic and institutional characteristics-such as, intensity of unionization/works councils and provision for apprenticeship training. Apprenticeship system in Germany requires private firms to provide training and on-the-job vocational education to their employees. Because apprenticeship training is expensive, firms providing such

training are less willing to invest in automation in areas where apprentices are employed than their U.S. counterparts where no such apprenticeship training is provided to workers. However, because regional planning is attributed to local governments who often work independently, there exists significant variation in the degree and intensity to which apprenticeship system is adopted across local regions. Therefore, it is expected that regions providing higher investment in apprenticeship training will experience less significant polarization of middle-income and middle-skilled jobs (which are often areas where apprentices are employed) than regions providing lower apprenticeship. Unionization is also expected to have differing impact on employment polarization in Germany as compared to the U.S. Labor market institutions such as works councils in Germany correspond to well-established systems of employee representation at the establishment and firm level which give workers a number of rights to information, consultation, and co-determination on company decisions are also associated with promoting job security and rent-seeking activities of employees, and fostering human resource management practices in firms. However, the extent to which works councils influence employment dynamics exhibits not only cross-country variations, but also regional variations. More specifically, works councils are stronger in regions that are covered by collective labor agreements than regions under the uncovered industrial regime. Therefore, it can be expected that strength of works councils is significantly associated with the degree and extent to which employees are displaced by automation and off-shoring. Taking all these into consideration, the paper uses the task-based approach (Autor et al. 2003) in order to study the causes of regional variations in the impact of trade and technology on overall employment and occupational composition in Germany.

Method: The empirical methodology is based on three databases: the Qualification and Career Survey (QCS) data from BIBB/IAB for 1979-2012, the Sample of Integrated Labour Market Biographies Regional file for 1975-2010 (SIAB-R) and the BIBB vocational education reports for 1977-2012. The paper proceeds in the following way: With respect to task-composition and occupational classifications, task-intensity measures are calculated on the occupational level using the QCS-BIBB data as share of activities an individual performs out of a given category (routinized, manual or cognitive) and then aggregated to the regional level by matching the BIBB data with the SIAB-R (1975-2010). The same procedure is also adopted to calculate usage of computers and ICT as proxy for technology adoption. With regard to trade exposure, bilateral sector-level data on imports for Germany is used and then aggregated on the regional-level. Finally, concerning the main variables of interest, intensity of apprenticeship training is measured as the share of new apprenticeship contracts introduced in a single year over the employed population within each region. Data is collected from the BIBB vocational education reports 1977-2012 for all local employment districts in West Germany, which is also the source for data on unionization, works councils and collective labor agreements.

Results: First results confirm the theoretical arguments that regions in Germany providing greater apprenticeship training are subjected to slower adoption of technology, lower offshorability of routine jobs and an overall lesser magnitude of employment polarization than their U.S. counterparts. Furthermore, significant sectoral differences are found with respect to manufacturing and service industries.

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Employment Polarization in Germany: Role of Technology, Human Capital and Trade

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Draft version

1. Background

The analysis of the impact of Human Capital (HC) on economic growth deals with the processes by which individuals develop usable knowledge that is employed in the context of occupational tasks. The archetypal view of HC provides the foundations of the Skill Biased Technical Change (SBTC) hypothesis, that is, the expectation that the complementarity between physical capital and HC triggers a bias in the demand for highly skilled workers to the detriment of low skilled ones (Goldin and Katz, 2009). In recent years this tenet has been widely criticized. On a conceptual level it has been pointed out that the mono-dimensional portrayal of human know-how underpinning SBTC neglects that workers perform a variety of job tasks, and, that different tasks require different types of skills. Therefore, changes in technology may affect differently the demand for certain types of tasks and the way in which skills are assigned to these different tasks (Acemolgu and Autor, 2012). In reality, it is argued that new technology exerts a 'selection effect' on some job activities and on the associated know-how, rather than on the entire vector of occupational tasks. A second weakness concerns the inability of the SBTC hypothesis to accommodate empirical evidence on employment polarization, in particular, fast growth of high-skilled and low-skilled workers accompanied by a decline in the demand for middle-skills occupations such as clerical and manufacturing jobs (Krusell et al., 2000; Autor et al., 2008; Goos et al., 2009). As this pattern is observed in coincidence with the diffusion of Information and Communications Technology (ICT), the conjecture that an increase of capital intensity favours monotonically workers with higher levels of skills has been decisively refuted (Goldin and Katz, 2009; Acemoglu and Autor, 2012).

From these critiques, stems a burgeoning literature on the relations between technology and labour, and on the determinants of employment polarization. Two explanations stand out. The first is that ICT is a substitute for human labour in 'routine' tasks

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that are the core of middle-skill occupations such as clerical jobs (Autor et al., 2003; Goos and Manning, 2007). The second refers to the effects of globalization and, in particular, job outsourcing and trade competition from China and India which, taken together, are major sources of job losses in manufacturing (Autor et al 2013; Lu and Ng, 2013 – for an alternative view on this: Bloom et al., 2013). The interpretative framework underpinning the empirical analysis of these forces focuses on the changes in the skill content of occupations. This approach, known as the 'task-based' model accommodates crucial findings of labour market changes due to the diffusion of technology and the imbalances brought about by international trade.

For what concerns technology, the starting point is the recognition that machines perform better physical and cognitive 'routine' tasks that can be codified in the form of instructions while humans retain a cognitive comparative advantage at 'non-routine' activities that involve complex pattern recognition. Accordingly, the framework proposed by Autor, Levy and Murnane (2003) builds on three empirically informed pillars. First, computer capital is more efficient in carrying out codifiable instructions and therefore has potential to substitute for workers in tasks that require cognitive or manual skills that can be accomplished by following explicit rules, also referred to as *"routine tasks"*. Examples include routine cognitive tasks, such as administrative activities, machine operation, production, clerical and office-related activities, quality control, documenting, measuring and monitoring machine operation, production, clerical and office-related activities, quality control, documenting, measuring and monitoring, or routine physical activities such as controlling machines and processes, operating vehicles and devices, sorting items. On the other hand computer capital is a complement to occupations that involve highly complex *"non-*routine *tasks"* such as problem-solving, creative, analytical and interactive skills. Examples of such tasks are scientific research, analysing data or information, making managerial and administrative decisions, creative thinking, evaluating the quality and standard of products and services, providing consultation and advice to clients, resolving conflicts and mediating negotiations, buying and selling, training and educating others, and providing guidance, motivation and advice to subordinates. Lastly, there is a broad range of occupations requiring physical dexterity and adaptability that are intensive in non-routine *"*manual tasks*"*, and are not prone to substitution by machinery given the high level of hand-eye coordination needed to perform such tasks. Examples are construction workers, security guards, waiters and janitors, unskilled medical and health-care personnel, truck drivers, house-cleaners and other menial labourers. Figures 1 plots the percentage point changes in employment shares of nine major occupational groups throughout 1979-2012 in Germany. Evidently, and consistent with the SBTC hypothesis, we see an overall decline in the employment shares of routine-intensive occupations viz. agriculture, production and clerical/office jobs that are more likely to be substituted by automation and technology, and a rapid growth of high-skilled abstract and professional occupations that are complementary to computerization. However, a strong polarization pattern in employment arises given a rapid increase in the share of low-skilled and low-income service occupations during the 1979-2012 period, pointing towards a "reallocation" effect from routine-intensive occupations to non- routine manual occupations (Autor and Dorn 2013).

Figure 1

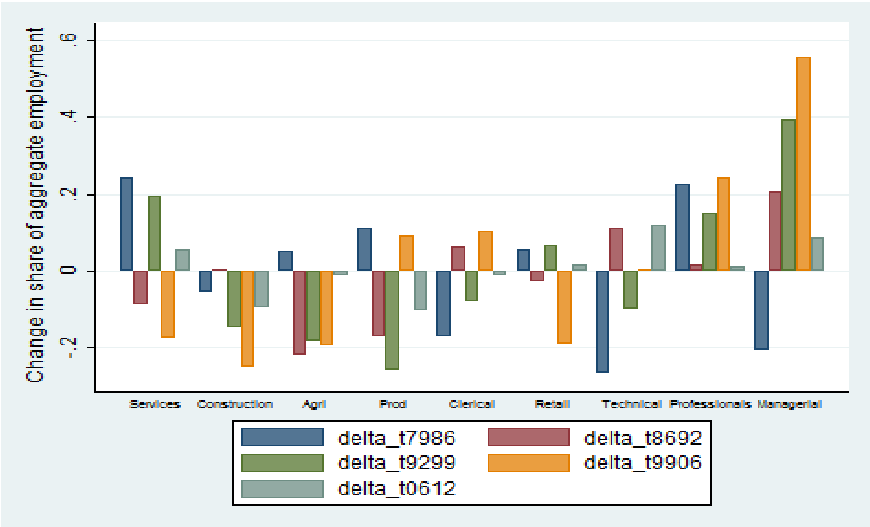
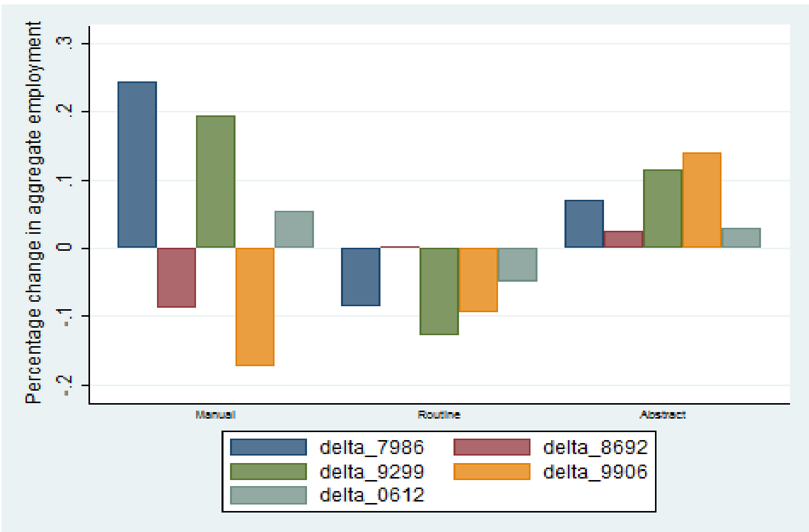


Figure 2 aggregates the nine occupational categories into three broad groups: manual, routine and abstract, and shows a similar U-shaped pattern in the share of employment since 1979. However, while routine employment share continues to decline over the entire time-period, growth in high-skilled abstract and low-skilled service occupations has considerably waned down during the 2000s.

Figure 2



This debate has been further enriched by the addition of international trade as a driver of transformations in the configuration of workforce skills, especially in the wake of the remarkable expansion of China and other emerging economies during the 2000s. Evidence on the US suggests that high exposure to foreign competition has a negative employment effect (Pierce and Schott, 2012; Autor et al, 2013) due to the combination of two forces: greater fragmentation of supply chains (Baldwin, 2011) which facilitated the offshoring of routine tasks involving minimal complexity (Blinder, 2009); and, secondly, the switch on the part of producers to higher quality products and innovations that require intensive use of Non-Routine tasks (Verhoogen, 2008). A recent study by Autor, Dorn and Hanson (2014) on the incidence of technology and trade across local labour markets in the US finds that while technology shifts the job composition within sectors, trade competition has a broader impact and depresses employment across all occupational groups, and especially high-skilled managerial, professional, and technical jobs in manufacturing. This work also shows that the timing of the impact of trade differs from that of technology, in that the former is faster whereas the latter is slower due to higher switching costs of converting established production methods. On the whole, the extent of routinization is found to vary significantly depending on the timing and specific characteristics of the region, such as the long-term patterns of industrial specialization.

We argue that the 'task-based' approach outlined above is an appealing conceptual framework for the study of structural changes in the workforce. To begin with, it allows for a more flexible interpretation of the relation between labour and capital in performing job tasks, and this is especially relevant in those contexts in which technology plays a dual role, partly complementing and partly substituting human work (Autor, 2013). Furthermore, this framework has demonstrated a better explanatory power also for the analysis of the impact of trade (Acemoglu and Autor, 2012; Autor and Dorn, 2013).

In spite of widespread consensus on the role of these global forces, the expectation is that they play out in very peculiar ways within specific contexts. There is no single top-down path to economic development, and the contribution of HC to productivity growth and competitiveness is contingent to the particular circumstances of the attendant local economy. Accordingly, there is demand for country-specific evidence that can elucidate the extent to which the changes triggered by technology and trade are amplified or hampered by local institutions. The present paper takes the cue from this backdrop and proposes an empirical analysis of the structural changes in the employment structure of Germany. The main focus is on the dynamics of local labour markets, that is, on harmonized territorial units identifiable on the basis of commuting flows of HC as well as cross-firm linkages that underpin geo-localized supply chains (OECD, 2002; Karlsson and Olson, 2006; Overman et al., 2010). In doing so, the project builds on and contributes to existing literature on job polarization by: (i) disentangling employment dynamics across local labour markets in Germany; (ii) assessing the extent of traditional forces such as technology (and trade), and whether the timing of their impacts is coincident with those of U.S. based studies; (iii) (examining the effect of institutional factors such as apprenticeship training on regional employment structure), and, (iv) articulating how these effects played out across sectors and occupations, and among workers of different education, age and gender.

2. Employment Polarization: Regional Labour Markets

The starting point of the paper are the most recent studies by Autor and Dorn (2013), and Autor, Dorn and Hanson (2014) which provide a unified explanation on the growth of low-skill service occupations in U.S. labour markets and the role of trade and technology therein. Surprisingly, authors find limited overlap in the exposure of local labour markets (commuting zones or CZs in the U.S.) to trade and technology and important sectoral, demographic and regional differences. Specifically, trade-exposed CZs are found to experience not only a greater decrease in routine task-based employment, but also a significant overall reduction in manual and non-routine-based employment in the manufacturing sector. On the other hand, CZs with a higher percentage of routine-task-intensive employment are found to display no such reduction in overall employment but a significant shift in job composition from the manufacturing to the service sectors. Authors relate these results to significant differences in the speed of adjustment to trade and technology shocks across regions and sectors, thereby proposing the need to understand regional variations in employment and wage patterns. This forms the basis of the present paper.

Local regions in Germany vary extensively not only in administrative and political attributes but also in several socio-economic and institutional characteristics-such as, intensity of unionization, presence of works councils and collective labour agreement, minimum wage requirements, provision for apprenticeship training and vocational education. The apprenticeship system in Germany, for example, requires private firms to provide training and on-the-job vocational education to their employees. Because apprenticeship training is expensive, firms providing such training are less willing to invest in automation in areas where apprentices are employed than their U.S. counterparts where no such apprenticeship training is provided to workers. However, because regional planning is attributed to local governments who often work independently, there exists significant variation in the degree and intensity to which apprenticeship system is adopted across local regions. Therefore, it is expected that regions providing higher investment in apprenticeship training will experience less significant polarization of middle-income and middle-skilled jobs (which are often areas where apprentices are employed) than regions providing lower apprenticeship. Autor and Dorn (2013) further relate employment polarization to the growth of low-skilled service occupations in the U.S. labour markets and find that routine-intensive labor markets are prone to experience greater reallocation of low-skilled routine labourers to service occupations. (Note to self: skill downgrading vis-a-vis skill upgrading, possibility of reallocation of routine labourers to high-skill routine jobs?) In case of Germany, apprenticeship training is found to be more prominent in the traditional manufacturing sector, which makes inter-industry reallocation somewhat sticky when compared to the U.S. Therefore, exploiting regional variations in the growth of non-routine service jobs in the presence of a strong vocational education system becomes an important objective of the current paper.

3. Data and Methodology

For the empirical analysis, the paper draws information from fourmain databases: the Qualification and Career Survey (QCS) data from BIBB/IAB (BundesinstitutfürBerufsbildung and InstitutfürArbeitsmarkt und Berufsforschung) for 1979-2012, the Sample of Integrated Labor Market Biographies Regional file for 1975-2010 (SIAB-R), the BIBB vocational education reports for 1977-2012, and sector-level trade data from UN Comtrade database.

With respect to task-composition and occupational classifications, we exploit six waves of the QCS(1979, 1986, 1992, 1999, 2006 and 2012) that provide detailed information on workplace characteristics, worker portfolio, occupational classifications and most importantly, occupational skill-requirements and adoption of computer and information technology at workplace for more than 30,000 individuals each year in Germany[1]. In each of the six surveys, occupational skill requirements are defined in terms of “tasks” that workers are required to perform at the workplace. Examples include machine operation and control, material production, repair and maintain, research, typing and book-keeping, negotiate,

[1]QCS 1979, 1986 and 1992 cover only West Germany, while the later 3 waves (QCS 1999, 2006 and 2012) cover employees from both East and West Germany.

organize, accommodate protection and security. However, given repeated changes in the survey constructs over time, not all tasks appear systematically in each wave. Furthermore, there are significant differences in the way tasks are reported across waves: while in some waves (1979, 1992) workers are asked to indicate whether they performed a particular task or not, in some waves (1986, 1999, 2006, 2012) workers are asked to indicate how frequently they were required to perform a particular task. In order to make the job-activities longitudinally comparable, we therefore follow Spitz-Oener (2006) and pool the tasks into five broad task categories: non-routine analytic, non-routine interactive, routine manual, routine cognitive and non-routine manual. We also reduce the categorical-classification of task activities into a binary classification, which indicate whether a particular task is performed or not. Based on these adjustments, task scores are then calculated as the share of activities an individual performs out of a given category. Specifically, we define individual task-intensity measures in the following way:

$$Task_{i,t}^{j} = \frac{number\ of\ activities\ in\ category\ j\ performed\ by\ individual\ i\ in\ time\ t}{total\ number\ of\ activities\ in\ category\ j\ at\ time\ t} * 100$$

where,

$j = 1\ (nr\ analytic), 2\ (nr\ interactive), 3\ (r\ cognitive), 4\ (r\ manual)\ \ and\ 5\ (nr\ manual)$

and $t = 1979, 1986, 1992, 1999, 2006\ and\ 2012$.

The individual task-scores are then aggregated on the occupational level by calculating the average task-measures of all workers with the same occupation. The first five surveys use the same occupational classification (KldB88-2digit), while QCS 2012 follow the Klassifizierung der Berufe, 1992 (KldB92-2digit). In order to construct a panel of systematically-consistent occupations across all waves, we manually reclassify occupational information of survey 2012 into KldB88- 2digit and finally end up with 80 unique two-digit occupational categories in each wave. The measure for technology and computerization at the occupational level is constructed following a similar procedure as the task-measures, defined as the share of employees in each occupational class using computers, data-processing machines, and/or computer terminals at workplace.

In order to assess the role of technology, human capital and trade in shaping employment pattern in local labour markets in Germany, the task-content and technology measures from BIBB/IAB are matched with the SIAB-Regionalfile on the occupational level. The Sample of Integrated Labour Market Biographies 1975-2010 (SIAB-R 7510, SUF) is a 2% random sample drawn from the Integrated Employment Biographies (IEB) of the Institute for Employment Research (IAB) that provides detailed information on demographic characteristics, educational background and vocational training of marginal, part-time and full-time workers, daily wage and benefit rate of employees subjected to social security, current occupation (classification based on KldB88-2digit), occupational-status, industry affiliation and place of work (district-level). We restrict the sample to workers between 17 and 64, and exclude the public sector. Using this matched data, the regional task-measures are calculated in three steps. First, the occupational task-scores are further grouped into three categories: abstract (non-routine analytic and non-routine interactive), routine (routine manual and routine cognitive) and manual (non-routine manual) for each occupational class. Second, and following the seminal paper by Autor, Levy and Murnane (2003),the three task-measures are combined into a summary measure of routine task-intensity calculated as:

$$RTI_{k,1979} = ln(Task^{R}_{1979}) - ln(Task^{A}_{1979}) - \ln(Task^{M}_{1979})$$

where $Task^{R}_{1979}, Task^{A}_{1979}$ and $Task^{M}_{1979}$ are respectively routine, analytic and manual task-content in occupation k in 1979. The following summary table gives a brief overview of the task-content of major occupation groups in 1979.

Table 1: Task-intensity measures by major occupation groups

Occupation	Abstract	Routine	Manual	RTI
Agriculture	5.100	19.076	8.377	1
Services	5.837	7.605	10.566	0
Construction and Trade	4.087	5.380	14.206	0
Production	4.266	10.069	4.663	1
Clerical/Office related	6.844	26.802	1.742	1
Retail	17.214	15.433	3.241	1
Technicians	16.848	12.415	9.420	0
Professionals	17.858	16.122	5.562	0
Managerial/Executive	24.823	22.183	5.139	0

Table 1 indicates the abstract, routine and manual task scores for each occupational category. The final column indicates whether the average RTI index in each occupational groupis larger (1) or smaller (0) than the average RTI score across all occupational groups. RTI=1 indicates that an occupation is routine-intensive, while RTI=0 indicates otherwise.

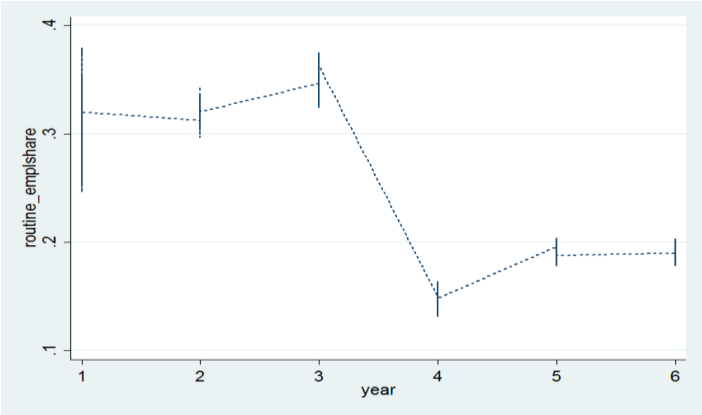
Finally, the share of routine occupation in each local region $r$in time $t$is calculated as:

$$Routineshare_{r,t} = \frac{\sum_{k=1}^{K} L_{k,r,t} * RTI_{k,1979}}{\sum_{k=1}^{K} L_{k,r,t}}$$

where $L_{k,r,t}$is the employment share in occupation k in labor market r in time t and $RTI_{k,1979}$ is the routine task-intensity measure for each occupation k in base year 1979. The above expression therefore indicates the share of routine-intensive employment in total employment in local region r in time t.

Figure 3 provides a graphical illustration of the regional share of routine-intensive occupations (Routineshare) during the period 1979-2012 in Germany. Clearly, average employment in routine occupations is found to have contracted significantly since 1992 (year=3) and presents first evidence on the polarization hypothesis.

Figure 3



With regard to trade-exposure of local labour markets, sector-level data on imports for Germany are to be collected from United Nations Comtrade database and then aggregated on the regional-level using the methodology proposed by Dauth (2014). This measure is interpreted as the share of aggregated sectoral import of goods in each local labour market in a particular time-period. Finally, data on apprenticeship training is to be collected from the BIBB vocational education reports 1977-2012 for all local employment districts in West Germany and is measured as the share of new apprenticeship contracts introduced in a single year over the employed population within each region.

4. Preliminary Results

Firstly, we estimate two separate regressions relating to computer adoption and routine-employment: a) routine-employment share in each local labour market in Germany at the start of the period (1979) on the percentage change in computer adoption in each region during the period 1979-2012 and b) routine-employment share in each local labour market in Germany at the start of the period (1979) on the percentage change in share of routine occupation in each region during the period 1979-2012. In other words, we estimate the following regression models:

$$a) \quad \Delta PC_{r,1979-2012} = cons_{+\beta_1} * Routineshare_{r,1979} + \gamma_s + \varepsilon_{r,1979-2012}$$

$$b) \quad \Delta Routineshare_{r,1979-2012} = cons_{+\beta_1} * Routineshare_{r,1979} + \gamma_s + \varepsilon_{r,1979-2012}$$

Simple OLS regression is run on 268 labor markets for West Germany until 1992 and 332 labor markets from 1999 onwards for both East and West Germany. Standard errors are clustered on the level of federal states. Furthermore, state dummies are included in the model, however not reported for simplicity.

Table 2: Change in computer adoption and routine-employment in local regions 1979-2012

Dependent Variables	Change in share of computer adoption	Change in share of routine employment
	Pooled OLS	Pooled OLS
Share of routine occupations $_{(t-1)}$	13.731*** (1.108)	-0.732*** (0.016)
Cons_	-0.525*** (0.075)	0.048*** (0.001)
R^2	0.974	0.993

Dependent Variables	Change in share of computer adoption			Change in share of routine employment		
	1979-1992	1992-2006	1979-2012	1979-1992	1992-2006	1979-2012
Share of routine occupations $_{(t-1)}$	17.225*** (1.523)	-7.128*** (3.573)	8.199*** (1.273)	-0.850*** (0.016)	-0.982*** (0.052)	-1.145*** (0.017)
Cons_	0.797*** (0.170)	6.172** (0.436)	7.459*** (0.142)	0.105*** (0.002)	0.062*** (0.006)	0.081*** (0.002)
R^2	0.604	0.232	0.302	0.880	0.736	0.978

*p <0.1, **p<0.05, ***p<0.01

Panel A: Number of observations =1864.Panel B: Number of observations = 268 (Column 1 and Column 4), Number of observations = 332 otherwise. Standard errors in parenthesis are clustered on state-level. State dummies are included. Year dummies included for stacked regression (Panel A: Base year 2012). All regressions include intercept(s).

Column 1 of Table 2 (top panel) confirms that regions with a high initial share of routine occupation in 1979 experienced a greater adoption of computer and information technology over the entire period of 1979-2012. Column 2 denotes that regions with a higher share of routine-intensive occupations in the base year 1979 experienced larger decline in routine occupations since 1979. Similar results are also obtained (bottom panel) when estimating pooled OLS regressions with first-differenced dependent variables - computer adoption and share of routine employment- for years 1979-1992, 1992-2006 and 1979-2012 on the initial routine-share of occupations at the start of each period.

Secondly, we estimate the relationship between initial routine employment shares in each local labour market on the percentage change in the share of low and medium-skilled non-college service occupations throughout the entire period 1979-2012. Typically, we run the following model:

$$c)\quad \Delta Serviceshare_{r,1979-2012} = cons_{+\beta_1} * Routineshare_{r,1979} + \gamma_s + \varepsilon_{r,1979-2012}$$

As earlier, we first run OLS regressions for each time-interval 1979-1992, 1992-2006 and 1979-2012 where the dependent variable denotes the share of routine occupations at the start of each period and the independent variables are a) change in non-college medium-skilled service occupations over each period and b) change in non-college low-skilled service occupations over each period. Medium skilled service occupations include employment in the following sectors: consumer goods industry, hospitality industry, private and public household services, construction industry, sale maintenance and repair, and transport and communication sector, while low skilled service occupations only include employment in consumer goods industry, hospitality industry and public, private and household services (see Table 1 for overview on routine/abstract/manual task-measures). Additionally we include state dummies for all federal states in Germany and cluster the standard errors on the state level. Table 3presents the preliminary results from the estimation.

Table 3: Non-college service occupation& routine-employment in local regions 1979-2012

Dependent Variable	Change in share of medium-skilled service occupation $(X_t - X_{t-1})$		
	1979-1992	1992-2006	1979-2012
Share of routine occupations $_{(t-1)}$	0.184 (0.272)	-1.073* (0.524)	-0.942* (0.469)
Cons_	-0.061* (0.030)	0.072 (0.064)	0.002 (0.052)
R^2	0.037	0.190	0.082

*p <0.1, **p<0.05, ***p<0.01
Number of observations = 268 (Column 1 and Column 3), number of observations = 332 (Column 2). Standard errors in parenthesis are clustered on state-level. State dummies are included. All regressions include intercept(s).

The overlap between regional routine employment and growth of medium skilled service occupations is weakly evident from Table 3. Period 1979-1992 presents significant but negative coefficient for share of routine occupations in 1979 while no significant relationship is found for 1979-1992. These results are however intuitive, given the fact that growth in low skilled service occupations appear to be the major driver for lower-tail polarization pattern in Germany (Figure 1) as routine workers are more likely to move down the skill-ladder rather than up. Therefore, we next consider only low-skilled non-college service occupations and examine whether decline in routine employment can be accounted by growth in employment in low-skilled manual and service jobs. We run stacked OLS regression where we include first differenced measure of low-skilled non-college service occupations over 1979-2012 and routine employment share at the start of each time period (see **Appendix** for results on medium-skilled service occupations). Additionally, further controls relating to share of women in total employment, share of employees with college education, share of 65+ adults in the total population, share of employment in manufacturing industry, and share of vocational trainees in total employment are step-by-step added to the model. Table 4 presents the results from the stacked OLS regressions.

Table 4: Low skilled service occupation and routine-employment in local regions 1979-2012

Dependent Variables	Change in share of non-college service occupations						
OLS regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Share of routine occupations $(t-1)$	0.259**	0.305***	0.327***	0.256**	0.182*	0.176*	0.304***
	(0.097)	(0.083)	(0.098)	(0.104)	(0.086)	(0.090)	(0.070)
Share with college degree $(t-1)$		0.073***					0.021
		(0.023)					(0.027)
Share of manufacturing empl $(t-1)$			-0.023***				-0.048***
			(0.006)				(0.010)
Share of female empl $(t-1)$				-0.066***			-0.119***
				(0.016)			(0.015)
Share of +65 in total empl $(t-1)$					0.042*		0.017
					(0.023)		(0.026)
Share of vocational empl $(t-1)$						-0.136**	-0.126*
						(0.038)	(0.067)
Cons_	-0.046**	-0.054***	-0.043**	-0.020	-0.062***	-0.027**	0.016
	(0.011)	(0.003)	(0.011)	(0.014)	(0.016)	(0.011)	(0.024)
R^2	0.152	0.160	0.160	0.168	0.155	0.160	0.200

*p <0.1, **p<0.05, ***p<0.01.Number of observations = 1864. Standard errors in parenthesis are clustered on state. State and year dummies included.

Column 1 of Table 4 only includes share of routine occupations at the start of each time period, and federal state and time dummies. The positive and highly significant coefficient of the variable confirms the prediction: initial share of routine occupations in each period is found to have significant effect on the percentage change in the share of low-skilled service occupations for the entire period, implying that regions with a greater share of routine jobs experienced greater growth of low-skilled service jobs in the subsequent periods. This goes in-line with Autor and Dorn’s (2013) hypothesis that employment polarization has resulted not only from ICT-adoption but also from changing consumer preferences. Column 2-6 are further augmented by demand-side factors that can have an effect on the growth of service occupations, and are explained next. The inclusion of share of high-skilled college educated employees in the total workforce significantly increases the coefficient of routine occupation and turns out to be highly significant by itself implying that greater share of workers with college/university degree predicts growth of non-college low-skilled service occupations. Column 3 strongly indicates that regions with a lower initial share of manufacturing employment experienced a higher growth of low-skilled service occupations, which is as expected. With regard to female employment and share of senior citizen in the total population (Column 4 and 5), overall significant effect is found. Regions with a higher initial share of senior citizen seems to have experienced a greater growth in low-skilled service occupations, confirming the theoretical understanding that aged population may have higher demand for low-skilled service assistance. However, regions with low female workforce share are found to experience greater growth in low-skilled service occupations. This is surprising, given that female workforce are more likely to be associated with household services and hospitality industry. Finally, share of vocational trainees in the total employment is found to be highly significant in predicting growth of service occupations; however it turns out to be negative. This result is highly intriguing for us, as it implies that regions with a lower share of trainees and vocationally-educated employees have experienced greater growth in low-skilled service occupations. Therefore the next course of analysis is to dig deeper into the system of vocational education and apprenticeship in Germany and examine how it has shaped employment and polarization pattern in local regions in Germany. As pointed out earlier, we expect human capital/provision of training to be a significant contributor to adoption of technology, decline of routine occupations and growth of low-skilled service occupations. Finally, Column 7 simultaneously includes the main variable of interest and the controls and results more or less remain the same.

Next we allow for heterogeneity in employment pattern across subgroups distinguished by age and gender and examine if initial share of routine-occupations in 1979 has differently affected share of routine employment and medium- and low-skilled service employment during the entire period 1979-2012 for the different subgroups. Accordingly, we split the sample into a) young workers (17-29), prime-age workers (30-54) and older workers (55-64) and b) male and female. Table 5 and 6 present the results.

Table 5: Change in regional employment share in each age group during 1979-2012

Dependent Variable	Change in share of routine employment for all employees		
	Young (21-29)	Prime(30-54)	Older(55-64)
Share of routine occupations $_{(1979)}$	-1.130***	-1.145***	-0.563***
	(0.023)	(0.016)	(0.039)
Cons_	0.080***	0.081***	0.037***
	(0.003)	(0.002)	(0.003)
R^2	0.896	0.978	0.457
Dependent Variable	**Change in share of medium-skilled non-college service employment**		
	Young (21-29)	Prime(30-54)	Older(55-64)
Share of routine occupations $_{(1979)}$	-0.594	-0.916*	0.416**
	(0.537)	(0.464)	(0.184)
Cons_	-0.036	-0.001	-0.031**
	(0.061)	(0.052)	(0.012)
R^2	0.069	0.081	0.056

Dependent Variable	Change in share of low-skilled non-college service employment		
	Young (21-29)	Prime(30-54)	Older(55-64)
Share of routine occupations $_{(1979)}$	0.878**	0.820**	0.122
	(0.357)	(0.340)	(0.156)
Cons_	-0.169***	-0.162***	-0.010
	(0.040)	(0.038)	(0.010)
R^2	0.137	0.133	0.074

*p <0.1, **p<0.05, ***p<0.01. Number of observations = 268. Standard errors in parenthesis are clustered on state-level. Federal state dummies included. All regressions include intercept(s). Results correspond to employees subjected to social security, aged between 17 and 64.

Panel A of Table 5 shows that, as expected, regions with a high initial share of employment in routine-occupations in 1979 experienced an overall decline in the share of routine occupations between 1979 and 2012. The decline is evident for all age-levels; however they are more prominent in case of young and prime-aged workers than older workers. Panel B and C distinguish between medium-skilled and low-skilled service occupations and present two interesting observations: point estimate for older workers in column 3 of Panel B is positive and highly significant, while that for prime-aged workers in column 2 is weakly significant but negative. On the other hand, young and prime-aged workers are more likely to engage in low-skilled non-routine service occupations than older workers. In summary, relative declines in routine-employment in regions are found to be offset by relative gains in non-college low-skilled service occupations, with higher gain in employment for younger and prime-aged workers. Moreover, only the older age group is found to gain employment in medium-skilled service occupations (column 3 of panel B), while no significant effect is found with regard to young and prime-aged workers. Evidently, employment polarization in local regions shifts employment mainly to low-skilled service jobs.

Table 6: Change in regional employment share by gender during 1979-2012

Dependent Variable	Change in share of routine employment by gender	
	Female	Male
Share of routine occupations $_{(1979)}$	-1.140***	-1.145***
	(0.017)	(0.017)
Cons_	0.081***	0.081***
	(0.002)	(0.002)
R^2	0.957	0.979

Dependent Variable	Change in share of non-college service employment			
	Female		Male	
	Medium-skilled	Low-skilled	Medium-skilled	Low-skilled
Share of routine occupations $_{(1979)}$	-1.075**	0.396	-0.942*	0.820**
	(0.475)	(0.347)	(0.469)	(0.351)
Cons_	0.018	-0.115**	0.002	-0.162**
	(0.054)	(0.039)	(0.052)	(0.039)
R^2	0.093	0.113	0.082	0.132

*p <0.1, **p<0.05, ***p<0.01. Number of observations = 268. Standard errors in parenthesis are clustered on state-level. Federal state dummies included. All regressions include intercept(s). Results correspond to employees subjected to social security, aged between 17 and 64.

Table 6 considers employment pattern by gender observable during the entire 1979-2012 period. The relationship between initial level of routine-occupations in local regions in 1979 and subsequent change in routine-occupation share is found to be alike for both male and female (panel A) implying that polarization has affected both genders in the same way. However, the high and significant point estimate of routine-occupations for male workers in column 4 of panel B as compared to the positive but insignificant coefficient for female workers in column 2 of panel B indicate that regions with a higher initial share of routine-employment experienced greater reallocation to low-skilled service occupations mainly for male workers.

Next steps include accounting for regional variation in educational system in Germany (preliminary data from BIBB vocational education reports 1977-2012), using trade-intensity as an additional factor (sector-level trade data from UN Comtrade database) and accounting for unobserved factors that causes routine-employment to vary across regions (potential instrumental variable estimation).

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APPENDIX:

Table 3b: Non-college low-skilled service occupation& routine-employment in local regions 1979-2012

Dependent Variable	Change in share of low-skilled service occupation ($X_t - X_{t-1}$)		
	1979-1992	1992-2006	1979-2012
Share of routine occupations $_{(t-1)}$	0.579*** (0.151)	-0.105 (0.311)	0.820** (0.351)
Cons_	-0.105*** (0.017)	-0.015 (0.038)	-0.162*** (0.040)
R^2	0.168	0.320	0.132

*p <0.1, **p<0.05, ***p<0.01
Number of observations = 268 (Column 1 and Column 3), number of observations = 332 (Column 2). Standard errors in parenthesis are clustered on state-level. State dummies are included. All regressions include intercept(s).

Table 4a: Pooled: Service occupation and routine-employment in local regions 1979-2012

Dependent Variables	Change in share of non-college medium-skilled service occupations						
OLS regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Share of routine occupations $(t-1)$	-0.141 (0.172)	-0.186 (0.171)	-0.399* (0.191)	-0.143 (0.174)	-0.256 (0.199)	-0.360 (0.215)	-0.609** (0.226)
Share with college degree $(t-1)$		-0.069** (0.027)					-0.054** (0.024)
Share of manufacturing empl $(t-1)$			0.085*** (0.011)				0.089*** (0.016)
Share of female empl $(t-1)$				-0.036 (0.029)			0.076* (0.040)
Share of +65 in total empl $(t-1)$					0.062*** (0.020)		-0.030 (0.037)
Share of vocational empl $(t-1)$						-0.357** (0.121)	-0.367** (0.153)
Cons_	0.007 (0.011)	0.015 (0.010)	-0.006 (0.009)	0.024 (0.018)	0.010 (0.012)	0.043** (0.019)	-0.001 (0.023)
R^2	0.258	0.261	0.301	0.259	0.260	0.281	0.324

*p <0.1, **p<0.05, ***p<0.01.Number of observations = 1864. Standard errors in parenthesis are clustered on state. State and year dummies included. Regressions are weighted by the share of regional employment in national employment at the start of each period.