The Polarization of Employment in German Local Labor Markets*

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Abstract

This paper uses the task-based view of technological change to study the phenomenon of employment and wage polarization at the level of local labor markets in Germany between 1979 and 2007. We exploit regional variation in the prevalence of employees performing routine tasks at the workplace before computerization started to spur, which reflects a region's potential of being affected by technological change. We relate this measure of regional routine intensity to subsequent employment trends and observe that initially routine intensive regions have witnessed a differential displacement of routine employment and a higher reallocation towards non-routine employment. We show that the personal service sector, which we find to be the main driver of employment polarization, has grown stronger in regions that are more affected by technological change. At the same time a higher regional routine share is related to higher unemployment, whereas we do not find effects on wages and migration flows.

Key Words: Job Tasks, Polarization, Technological Change, Service Occupations, Regional Labor Markets.

JEL Classification: J24, J31, J62, O33, R23.

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1 Introduction

For many industrialized countries, research has documented a polarizing pattern of the employment structure in recent decades. That is, employment growth of medium-skilled employees has deteriorated relative to employment gains of low- and high-skilled employees. As a main explanation for this development, literature has focused on the role of technological change and its implications for the employment structure. It is argued that ongoing technological progress together with a rapid decline in IT prices favors non-routine tasks performed by high- and low-skilled workers at the expense of routine tasks, which are mainly performed by medium-skilled employees, leading to employment polarization (Autor et al., 2003; Nordhaus, 2007).

This study empirically analyzes the forces behind the changing shape of low- and medium-skilled employment in the West German labor market. We explore the underlying shifts in the occupational composition and their relation to technological change. In particular, we study whether technological change is related to rising employment in the less-skilled service sector, which is hypothesized to be the main driver of employment growth at the lower tail of the wage distribution. Our analysis builds on recent work by Autor and Dorn (2012), who are the first to develop a general equilibrium model that explains employment and wage dynamics at the lower tail of the skill distribution in response to technological change using the task-based framework. In their model, human labor performing routine tasks is substituted by computer capital, as the price for information technology declines. This induces a movement of employment from routine towards non-routine tasks, whereas the decline in routine employment is primarily offset by a reallocation of labor towards *low-skill* non-routine tasks (i.e. non-routine manual tasks). The empirical analysis conducted by Autor and Dorn (2012) corroborates the model predictions, indicating that the polarizing trend is mostly attributable to the substantial growth of employment and wages of low-skilled personal service occupations in recent decades.

Our study contributes to the existing literature on polarization in West Germany by providing novel evidence at the level of local labor markets inspired by the analysis of Autor and Dorn (2012). Exploiting regional variation, we are able to directly relate technological change to subsequent regional employment developments. This advances existing literature, which has so far focused on the observation of trends at the national level. The key motivation for the regional approach is that non-routine manual tasks, which are prevalent in less-skilled personal services, are not tradable across regions. Therefore, demand shifts can be identified at the regional level. Furthermore, we exploit the fact that local labor markets differ in their industry specialization. These differences are reflected by the regional task structure and capture the potential of being affected by technological progress. To grasp this "automation potential", we generate an index that measures the share of routine labor in a local labor market before technological change has evolved. We then explore the predictions of the model, testing whether regions with a high routine share differentially experienced employment and wage polarization. To our knowledge, we are the first to employ the recently released *Sample of Integrated Labor Market Biographies Regional File (SIAB-R)* in the polarization context, which allows us to extend the time frame until the year 2008.

Our findings suggest that regions have differentially experienced technological progress and displacement of routine labor conditional on their initial task structure. We find that a region's initial routine share contains substantial predictive power for subsequent employment trends. First, we document

a robust positive relationship between the regional task structure and the growth of non-routine employment. We then show that especially *personal service occupations*, which require disproportionally high inputs of non-routine manual tasks and which we find to be the main drivers of positive employment growth at the lower tail of the wage distribution, have grown stronger in regions with a high initial routine share. We illustrate that employment growth in the personal service sector is primarily driven by female employees in the sample and more pronounced for older and part-time working women.

Although our employment results are in line with the model predictions in Autor and Dorn (2012), a cross-country comparison with the U.S indicates that the overall growth of service employment is larger in the U.S. than in Germany. One explanation for the difference in the magnitude of the phenomenon is presumably of institutional nature. Adjustment processes to technological change could be dampened by high payroll taxes and labor costs on the demand side. On the supply side, product market regulation and a generous unemployment benefit system might restrict labor mobility.[1] We investigate this hypothesis and indeed find that initially routine intensive regions experienced a larger increase in the unemployment rate. We furthermore discuss the possibility that employees migrate to other labor markets that are less affected by technological change. However, we find only very limited evidence that regions which are prone to technological change differentially experienced outward migration. Consistent with existing evidence for Germany, we do not find support for wage polarization at the level of local labor markets in our analysis. Taken together, our results complement existing research on polarization, showing that the general trend of a polarizing employment pattern is not unique to the U.S. but also prevalent in other industrialized countries.

The remainder of the paper proceeds as follows. In section 2, we provide an overview of the task-based framework and discuss the related literature and show stylized facts for Germany. In section 3, we describe the empirical approach, the data set and the variables used in our analysis. Section 4 presents descriptive evidence on trends in regional task intensities and information technology. We then investigate the relationship between the regional routine share and the growth of routine and non-routine employment, focusing on trends in personal service employment. In addition, we consider alternative adjustment mechanisms such as unemployment and migration. Furthermore, we analyze whether employment developments are accompanied by wage trends in the same direction. Section 5 concludes.

2 The Task-Based Approach and Employment Polarization

In order to analyze employment and wage changes in response to technological progress we build on concepts of the task literature initiated by Autor et al. (2003).[2] The key feature of the task-based approach is that it conceptualizes work into a series of tasks, characterized as *routine* and *non-routine*, depending on their substitutability or complementarity with computer technology. Routine tasks are well-defined and follow explicit rules, hence they are especially amenable to substitution by computer technology. In contrast, computers can neither substitute for *non-routine cognitive* tasks that involve high complexity

[1] One important example of product market regulation in the German context is the Trade and Crafts Code that potentially inhibits employment growth as it substantially restricts firm entry into certain product markets.

[2] See Acemoglu and Autor (2011) for a comprehensive overview of the task literature and Weiss (2008) for a model of the substitution of human routine tasks by computer capital.

and problem-solving nor for *non-routine manual* tasks which require environmental and interpersonal adaptability. Instead, non-routine cognitive tasks are complemented by computer technology, as they can be carried out more efficiently, resulting in productivity gains of employees performing these tasks. Non-routine manual tasks are not directly influenced by computerization. Yet, the demand for these tasks can be indirectly affected through a general equilibrium effect, according to which labor flows into a sector where productivity growth is low in order to keep the balance of output stable (Baumol, 1967). Following this argument, routine labor will reallocate into the non-routine manual "sector", as technology is not applied there.[3]

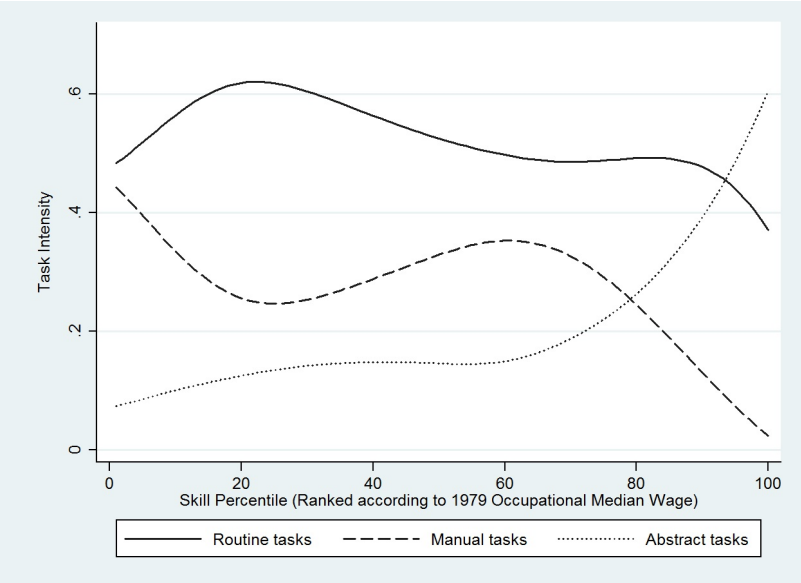
Employment polarizes because tasks are not evenly distributed across the skill distribution. Figure 1 depicts the distribution of task usage in occupations across the skill distribution, which is approximated by the occupational median wage in 1979. The Figure shows that routine tasks are prevalent in occupations in the middle of the skill distribution, while non-routine cognitive and manual tasks are mainly performed by either high- or low-skilled employees. Hence, a technology induced decline in the demand for routine tasks will result in a polarizing pattern of employment - a prediction reflected in the data. Figure 2 depicts employment growth ranked by skill percentile for different subperiods between 1979 and 2007, where an occupation's skill rank is approximated by the median wage of employees in the occupation in 1979. Between 1979 and 1989, occupations below the median skill level declined uniformly at the expense of employment gains of occupations at the upper tail of the skill distribution. Between 1989 and 1999, however, relative employment growth also started to spur at lower percentiles, while employment losses were concentrated among deciles in the middle of the skill distribution, resulting in the typical pattern of employment polarization. This development resembles trends in the U.S. as presented by Acemoglu and Autor (2011). In the most recent time period (between 1999 and 2007), this "U-shaped" employment growth is somewhat less pronounced, but still evident. So far, some initial support for employment polarization in Germany has been found by Spitz-Oener (2006) and Dustmann et al. (2009), while Black and Spitz-Oener (2010) show that polarizing trends are more pronounced for women than for men.[4]

Employment polarization is accompanied by wage developments in the same direction, if the increase in the supply of workers performing non-routine manual tasks is offset by an increase in the demand for these tasks. The model developed by Autor and Dorn (2012) shows that this will occur if goods produced by routine labor and services produced by non-routine manual labor are at least weakly complementary to each other. In this case, wages paid to routine labor deteriorate relative to wages paid to non-routine cognitive and non-routine manual labor. If, however, goods and services are not complementary, the demand for services does not rise sufficiently to increase the price for non-routine manual

[3] In their model, Autor and Dorn (2012) analyze employment and wage dynamics in a two-sector framework, where non-routine manual labor is exclusively used for the production of services, while the production of goods requires a combination of routine and non-routine cognitive tasks. They show that as technology replaces routine tasks, low-skilled labor will be drawn from the goods into the service sector, if goods and services are weakly complementary.

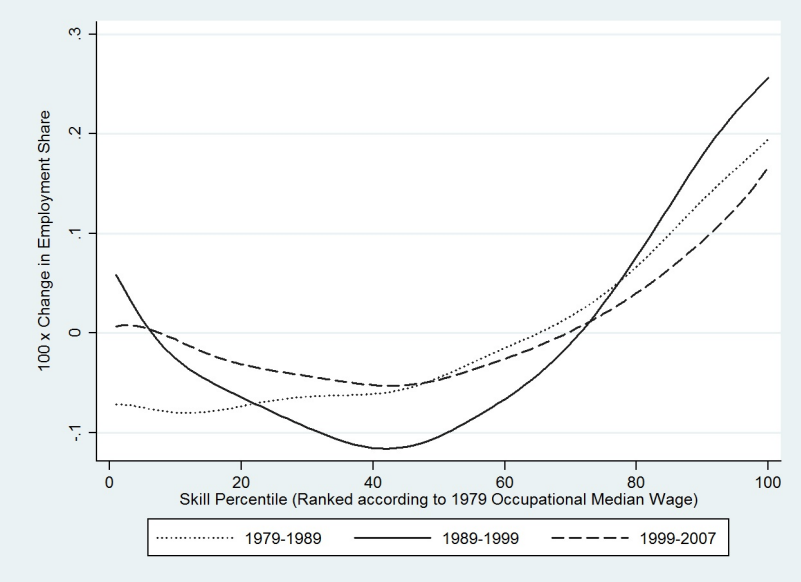
[4] In other industrialized countries, polarization studies have mainly focused on trends at the aggregate level. Autor et al. (2006) show that in the U.S., medium-skilled employment has deteriorated relative to low- and high-skilled employment starting in the 1990's, corroborating the conjecture that technological change is rather task- than skill-biased. Goos and Manning (2007) find similar trends for Great Britain, showing that employment in occupations with the lowest and highest median wages in 1979 experienced growth in subsequent decades, while employment in the middle of the distribution declined. Using data from the European Union Labour Force Survey, Goos et al. (2009) present similar evidence for labor market polarization in 13 European countries.

Figure 1: Task Inputs by Skill Percentile



Notes: Shares of workers performing routine, manual and abstract tasks. Occupations are ranked according to their 1979 median wage using the SIAB-R. Task intensity is derived from BIBB/IAB wave 1979 and defined as in Equation 2.

Figure 2: Smoothed Changes in Employment by Skill Percentile



Notes: Smoothed changes in employment by skill percentile in indicated periods. Occupations are ranked according to their 1979 median wage using the SIAB-R. Locally weighted smoothing regression with 100 observations and bandwidth 0.8.

relative to routine tasks and wage polarization will not occur.

Against the background of these theoretical considerations, evidence for wage polarization is rather ambiguous. For the U.S., Autor et al. (2008) have found that wages have polarized after 1985. Autor and Dorn (2012) furthermore show that wage increases for low-skilled service jobs have particularly con-

tributed to the polarizing pattern of wage growth. Yet, for Germany, the picture is different. Studies by Fitzenberger (1999) and Gernandt and Pfeiffer (2006) show that upper tail wage inequality has increased during the 1980's, while lower tail inequality has remained relatively stable presumably due to strong unions and implicit minimum wages. This is consistent with findings by Dustmann et al. (2009), who, in contrast to developments in the U.S., report *rising* lower tail inequality starting in the mid 1990's, a period that is characterized by strong deunionization trends. Antonczyk et al. (2010a) compare wage trends in Germany and the U.S. and conclude that wage inequality in both countries evolves too differently such that technology effects alone could explain the empirical findings. In sum, Germany seems to have experienced wage dispersion rather than compression at the lower tail of the wage distribution (Kohn, 2006; Antonczyk et al., 2010b, 2009).

3 Data and Methods

3.1 Empirical Approach and Estimation Strategy

The starting point of our analysis is the observation that, due to location-specific attributes, regions largely differ in their industry specialization pattern and hence in their task structure (Krugman, 1991). That is, depending on the task requirements for the production of goods, regions employ different shares of routine, non-routine manual and non-routine cognitive task inputs. Taken these regional differences as given, technological progress in the form of declining prices for computer technology should have a differential effect on regions conditional on their "automation potential", hence task structure, which we measure by the share of routine employment in a specific region before technology has evolved. We bring the theory to the data by testing five closely related predictions that can be derived from the theoretical model presented by Autor and Dorn (2012). In particular, we test whether regions characterized by a high initial routine employment share

1. adopt information technology to a larger extent,
2. exhibit a larger decline in routine employment,
3. experience larger growth in non-routine employment in general and larger growth in personal service occupations in particular,
4. witness a differential increase in unemployment and outward migration,
5. differentially experience wage developments.

In order to analyze the relationship between the regional task structure in 1979 and subsequent employment and wage changes between 1979 and 2007, we set up an empirical model of the following form:[5]

$$Y_r(\Delta t) = \alpha + \beta_1 TSH_r^R(t) + \beta_2 X_r(t) + \gamma_s + e_r. \tag{1}$$

[5]We chose the start and end year in such a way that they are similar with respect to their location in the business cycle. As the economy was hit by the financial crisis in 2008, we use data from 2007 instead.

Depending on which of the aforementioned predictions is tested, the dependent variable $Y_r(\Delta t)$ represents the change in one of the following measures in region r located in state s between the years 1979 and 2007: (1) share of employees working with a computer, (2) share of employees performing routine/non-routine manual/non-routine cognitive tasks (3) share of personal service employment in overall employment, (4) unemployment rate and net migration share and (5) different wage inequality measures.[6] Our main parameter of interest, β_1, is the coefficient on the measure of regional routine employment in 1979, $TSH_r^R(t)$. As is common in this body of literature, we argue that this measure is largely unaffected by technological progress as computerization only started to spur during the 1980's (Autor et al., 1998; Bresnahan, 1999).

All regressions include state dummies, γ_s, that control for mean differences in employment and wages across states. The vector $X_r(t)$ includes additional covariates to control for human capital (ratio of high- to low- and medium-skilled workers) and demographic composition (share of women/foreigners in the labor force) as well as for economic conditions (fraction of jobs subject to social security contributions in overall population) in 1979.

3.2 Data and Construction of Variables

Our analysis is based on three datasets, the BIBB/IAB Qualification and Career Survey,[7] the Sample of Integrated Labor Market Biographies Regional File (SIAB-R) and the Establishment History Panel (BHP). Information on the task requirements of employees is derived from the Qualification and Career Survey in 1979 which covers approximately 30,000 individuals. The dataset contains information on workplace characteristics and educational attainment and is particularly well suited for our research, as it includes detailed information on the tools and machines individuals use at the workplace and on the activities they perform.

These activities are pooled into three task groups: (1) non-routine cognitive, (2) routine and (3) non-routine manual tasks for each individual i. In the assignment of tasks, we follow Spitz-Oener (2006) and construct individual task measures TM_i^j for task j in the base year 1979 according to the definition of Antonczyk et al. (2009):

$$TM_i^j(1979) = \frac{\text{number of activities in category } j \text{ performed by } i \text{ in 1979}}{\text{total number of activities performed by } i \text{ over all categories in 1979}} * 100, \tag{2}$$

where $j = C$ (non-routine cognitice), R (routine), M (non-routine manual). The individual task measures are then aggregated in order to obtain a task index for each occupation k, where the task input of individual i in occupation k in 1979 is weighted by the number of its respective working hours per week

[6] Autor and Dorn (2012) employ stacked first differences over three time periods to estimate the relationship between regional routine intensity and the growth of non-college service employment. In contrast, we restrict our analysis to the single difference based on the routine shares and regional covariates in 1979 as the explanatory variables to focus on the long-run component of differences in regional task structures and thus circumvent the potential endogeneity problem related to the use of subsequent routine shares. If we follow the approach of Autor and Dorn (2012) we obtain very similar results in terms of effect size and statistical significance as shown in Appendix Table 3.

[7] This survey is conducted by the German Federal Institute for Vocational Training (Bundesinstitut für Berufsbildung, BIBB) in cooperation with the Research Institute of the Federal Employment Agency (Institut für Arbeitsmarkt und Berufsforschung, IAB) for the years 1979, 1986, 1992 and 1999. The last wave in 2006 was renamed and conducted by the BIBB and the Federal Institute for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, BAuA).

($L_{ik}(1979)$):

$$TI_k^j(1979) = \frac{\sum_i [L_{ik}(1979) \times TM_{ik}^j(1979)]}{\sum_i L_{ik}(1979)}. \tag{3}$$

To generate a task measure at the regional level, the occupational task information is matched to the SIAB-R, exploiting the fact that both datasets employ a time-consistent definition of occupational titles according to the three-digit 1988 occupational classification provided by the Federal Employment Agency.[8] The SIAB-R is a two percent random sample drawn from the full population of the Integrated Employment Biographies, which comprises marginal, part-time and regular employees as well as job searchers and benefit recipients covering the years 1975 to 2008 (for details, see Dorner et al. (2010)). It provides detailed information on daily wages for employees subject to social security contributions (wages of civil servants or self-employed workers are not included), as well as information on industry affiliation and location of the workplace and demographic information on age, gender, nationality and educational attainment.[9] Labor supply is measured by the number of days worked within a respective year. We restrict the sample to prime-aged workers between 20 and 60 living in West Germany and exclude public sector and agricultural employment. As a large fraction of less-skilled workers is employed part-time, only focusing on full-time workers might obscure employment developments particularly for this labor market group. Hence, we follow Dauth (2010) and weight part-time employment using information on whether an individual works full-time, major part-time or minor part-time.[10] However, in our empirical analysis we will elaborate on differences between part- and full-time employment.

Our definition of local labor markets builds on 326 administrative districts in West Germany. However, administrative districts have developed as a result of historical circumstances and do not necessarily depict regional economic entities. As it is crucial for our analysis to consider functionally delineated labor market regions, we further aggregate the administrative districts into 204 labor market regions, following the classification of the "Gemeinschaftsaufgabe *Verbesserung der regionalen Wirtschaftsstruktur*" (Koller and Schwengler, 2000). The advantage of this definition is that commuter flows are taken into account, thereby reflecting local labor markets more appropriately (Eckey and Klemmer, 1991). For each region r and time t the task shares $TSH_r^j(t)$ are then given as:

$$TSH_r^j(t) = \frac{\sum_k [L_{kr}(t) \times TI_k^j(1979)]}{\sum_k L_{kr}(t)}, \tag{4}$$

where $L_{kr}(t)$ is the employment in occupation k in labor market r in time t. For example, $TSH_r^R(1979)$ represents the fraction of routine employment in total employment in labor market r in 1979. It bears notice that our measure exploits the task requirements of *all* occupations, which distinguishes our routine share definition from the one used in Autor and Dorn (2012).[11] However, as we will discuss later, our results do not hinge on this particular choice.

[8] Due to data protection reasons the SIAB-R is anonymised in the form of a regional file. As a consequence the occupational information is aggregated to 120 occupation groups. However, occupations are unambiguously assignable to the three-digit 1988 occupational classification.

[9] Workers are classified based on their vocational education using the imputation algorithm developed by Fitzenberger (1999). Employees with no occupational training are considered as having a low level of education; employees with a vocational occupation who have completed an apprenticeship or graduated from a vocational college are classified as medium-educated and employees holding a degree from a technical college or university are considered highly educated.

[10] Labor supply of individuals working minor part-time (less than 18 hours) and major part time (18 to less than 39 hours) is multiplied with 16/39 and 24/39, respectively.

[11] In their analysis, Autor and Dorn (2012) classify occupations as routine intensive if they are located in the top third of the

Similarly to the task shares, we construct a measure for regional computer usage with information derived from the BIBB/IAB data that is matched to the SIAB-R at the occupational level. Regional computer prevalence is measured as the share of employees using one of the following devices: (1) personal computers, (2) terminals or (3) electronic data-processing machines in region r in 1979 and 2006.

For the analysis of wages, we use information on real gross daily wages of employees available from the SIAB-R to construct different measures of regional wage inequality, the P85/P15, P85/P50 and P50/P15 log daily wage ratios, respectively. We exclude part-time employment and weight the observations with the number of days worked in a respective year. Furthermore, we correct for the right-censoring of the data at the social security contribution threshold by imputing and replacing the topcoded wages following Gartner (2005).[12] Since 1984, one-time and bonus payments have been included in the wage measure, resulting in a spurious increase in earnings inequality (Steiner and Wagner, 1998). We account for this structural break by correcting the wage observations before 1983 following Fitzenberger (1999) and Dustmann et al. (2009).[13]

In order to construct regional control variables, we use information from the Establishment History Panel (BHP), a 50 percent sample of all establishments throughout Germany with at least one employee liable to social security, stratified by establishment size. We use information on the number of employees by different labor market segments (gender, nationality, educational level) and aggregate the information at the regional level. Descriptive statistics for the routine share and the regional covariates for the year 1979 are summarized in Appendix Table 1

4 Results

4.1 Task Specialization, Adoption of IT and the Displacement of Routine Tasks

We start our analysis by examining the main explanatory variable, the share of routine employment in 1979. The average regional routine share in 1979 is 0.537, suggesting that the fraction of routine tasks performed in overall employment in a region amounts to 53.7% at the mean. A region at the 85th percentile of the routine share distribution has a 4.3 percentage points higher routine intensity compared to a region at the 15th percentile (the value of the routine share at the 15th and 85th percentile is 0.518 and 0.561, respectively).[14]

routine task distribution in 1980. Their routine share is then measured as $TSH_r^j(t) = \frac{\sum_k L_{kr}(t) \times \mathbb{I}[TI_k^j(t) > TI_k^j(1980|P66)]}{\sum_k L_{kr}(t)}$, where $\mathbb{I}[\cdot]$ is an indicator function which takes the value one if an occupation is routine intensive and $L_{kr}(t)$ is labor supply in occupation k in labor market r at time t.

[12] We run a series of tobit regressions of log wages in each year, separately for each education group with several covariates. As additional controls we use a square in age, nationality, industry affiliation dummies, occupational categories and region dummies. Topcoded wages are then replaced by draws from normal distributions that are truncated and whose moments are determined from the tobit estimation.

[13] We thank Bernd Fitzenberger and Christian Dustmann for making the correction program available to us. Results of these regressions are available upon request.

[14] As the variation in the routine share is relatively small, the question arises whether the variation is systematic or rather a result of measurement error. To address this issue, we re-construct our routine share measure using employment data from a five year range between 1979 and 1983. Both routine shares are highly correlated (with a correlation coefficient of 0.96) and all estimation results remain virtually unchanged. Furthermore, we re-estimate our models using variations of the routine share measures as proposed in Autor and Dorn (2012), who construct their routine share measure using the top third most

To get an impression of the regional variation in routine intensity, Appendix Figure 1 maps the geographic distribution of the regional routine share in 1979 across Germany. Labor markets with a high share of routine employment are predominantly industrial strongholds, such as Wuppertal (0.58), Gütersloh (0.58) and Leverkusen (0.57) being home to industries such as textiles, chemicals, pharmaceuticals and automobiles. However, it bears emphasis that also labor markets that are specialized in relatively knowledge-intensive industries, e.g. Düsseldorf (0.57) and Frankfurt (0.56) are among the top-ranked routine-intensive labor markets. This is in line with the task-based approach, as these industries typically employ many supporting occupations, such as secretaries, bookkeepers and accountants, which are characterized by a high routine task content. Regions that have a low routine share are mainly specialized in tourism and hospitality, such as Garmisch-Partenkirchen (0.50) or Husum (0.49) which are located near the Alps and the coast, respectively.

The task-based approach suggests that computerization should have occurred differentially across regions conditional on their initial routine intensity, along with a differential displacement of routine labor. A simple OLS regression relating the difference in regional computer adoption between 1979 and 2006 to the initial routine share yields the following results:

$$PC_r(1979-2006) = 0.436 + 0.486 \times TSH_r^R(1979) + e_r \quad (t = 5.79) \tag{5}$$

In line with expectations, a higher routine share in 1979 is associated with larger subsequent computer adoption between 1979 and 2006. The highly significant coefficient implies that a region with the mean routine share of 0.537 in 1979 is predicted to increase the share of employees using a computer by 70 percentage points between 1979 and 2007. To interpret the economic magnitude of the estimated coefficient, we compare a region at the 85th percentile of the routine share distribution to a region at the 15th percentile and find a differential increase of 2.1 percentage points.[16] From these numbers we see that computer use increased tremendously across all regions over the observed period. Compared to this development, the implied differential resulting from varying routine shares is of rather small economic importance.

In a next step we test whether the difference in computer adoption is accompanied by a larger displacement of routine labor. Therefore, we regress the change in the regional routine share between 1979 and 2007 on the initial routine intensity applying a variant of equation 1, in which state dummies and population density are included as additional explanatory variables. The negative and highly significant coefficient estimate in column 1, Panel A of Table 1 corroborates the prediction. The estimate indicates that a region at the 85th percentile of the routine share distribution experienced a 2.2 percentage points higher displacement of routine labor compared to a region at the 15th percentile between 1979 and 2007. Given a decrease in routine employment of approximately 1.0 percentage point in a region with

routine intensive occupations instead of all occupations.[15] The variation in these measures is almost twice as high as in the routine share employed in this study. As shown in Appendix Table 3 the different variants yield similar results compared to our baseline model in terms of their effect size and statistical significance. The drawback of these measures, however, is that they rely on an arbitrarily chosen cut-off point.

[16]The effect for a region with the mean routine share is calculated as $0.436 + (0.486 \times 0.537)$. The percentile difference is calculated as $(0.561 - 0.518) \times 0.486$.

the mean routine share, the percentile difference implied by the estimated coefficient is of substantial economic significance. Consistent with the model implications, columns 2 and 3 of Table A confirm that the decline in routine employment is substantially larger for low- and medium-educated workers than for workers with a university degree.

Table 1: Changes in the Shares of Regional Routine and Non-Routine Employment, 1979-2007

Dependent variable: Δ task share 1979-2007	All Workers	High-skilled workers	Low- & medium-skilled workers
	(1)	(2)	(3)
		A. Δ Routine Share	
Routine Share 1979	-0.507***	-0.096	-0.503***
	(0.061)	(0.195)	(0.059)
R^2	0.277	0.074	0.275
		B. Δ Non-Routine Manual Share	
Routine Share 1979	0.443***	-0.285*	0.477***
	(0.063)	(0.155)	(0.059)
R^2	0.280	0.054	0.300
		C. Δ Non-Routine Cognitive Share	
Routine Share 1979	0.064	0.381*	0.026
	(0.056)	(0.206)	(0.041)
R^2	0.114	0.070	0.137

Notes: N = 204 labor market regions. All models include dummies for the federal state in which the region is located, a measure of population density (number of inhabitants per square kilometer) as well as a constant. High skilled workers are those with at least a technical college or university degree. Robust standard errors in parentheses. * Significant at 10%, ** at 5%, *** at 1%.

We now turn to the question how employment adapts to the shift in labor demand induced by the ongoing routinization process. The task-based framework predicts that declining demand for routine tasks is offset by employment gains in either non-routine cognitive or manual labor. If the performance of non-routine cognitive tasks requires a relatively high skill level or some educational attainment that is not met by workers who formerly engaged in routine tasks without additional training, labor should reallocate predominantly towards the performance of non-routine manual tasks. Specifically, we estimate two separate models as described by equation 1, where the change in the non-routine manual (Panel B) and the non-routine cognitive employment share (Panel C) in region r between 1979 and 2007 is regressed on the initial routine share, state dummies and population density, respectively. The results in the first column of Panel B and C show that relative declines in routine intensive employment are primarily offset by employment gains in non-routine manual jobs. Yet, this development does not occur uniformly across educational groups as suggested by columns 2 and 3. The growth of non-routine manual employment is entirely realized by workers with a medium or low level of education, while the share of high-skilled workers performing manual tasks is even negatively related to initial routine intensity.

In contrast, gains in employment performing non-routine cognitive tasks are positive and significant among high-skilled workers, while this does not hold true for workers without a university degree.[17] Thus, our findings are consistent with studies by Cortes (2011) and Autor and Dorn (2009), who provide empirical evidence that occupational mobility of routine workers into non-routine cognitive and manual employment is different across age and skill groups.

4.2 The Growth of Personal Service Sector Employment

4.2.1 *Overall Trends in Major Occupational Groups*

So far, we have shown preliminary evidence of a significant technology related shift away from routine towards non-routine employment at the level of regional labor markets. Bearing in mind the polarizing pattern of employment depicted in Figure 2, the question arises whether this growth in non-routine manual tasks indeed drives the twisting of the lower tail of the wage distribution. To investigate employment changes in greater detail, Table 2 lists the occupations in the highest quintile of the non-routine manual task distribution alongside their location on the wage distribution (as measured by the occupational median wage in 1979) and their share of low-skilled employment. The table indicates that two broad occupational categories dominate the group of manual intensive occupations. One category that can be identified is the group of personal service occupations, classified according to Blossfeld (1985). These occupations involve assisting and caring for others, such as hairdressers, cleaners, table waiters and security guards.[18]

The second occupational group that is characterized by high non-routine manual task inputs are manual production occupations, such as watchmakers, locksmiths and carpenters. Although production and personal service occupations are similar in their tasks requirements, it bears notice that both groups differ significantly from each other with respect to their skill content as well as their location on the occupational wage distribution. With an employment weighted average log wage of 4.07, the personal service occupations are mainly located at the bottom of the wage distribution, while employees performing production occupations earn on average 20 percent more. Furthermore, with an employment weighted average of 41.3%, the share of employees without formal education in personal service occupations is more than twice as high as the respective number for production occupations (13.9%).

Although personal service occupations are characterized by a low skill and wage level, the share of employees performing these occupations grew by roughly 15% between 1979 and 2007 and makes up for 20% of overall employment in 2007 (see Table 3). Growth in service employment is concentrated in the 1990's, a period that - as we have shown earlier in Figure 2 - is characterized by strong employment polarization. Table 3 additionally depicts the aggregate development of employment shares separately by gender. Although the share of employees working in service occupations grew for men and women, the numbers reveal stronger increases in service employment for women of approximately 2 percentage

[17] It bears emphasis that the sum of the 3 task shares adds up to one by construction. Therefore, as a region's routine employment share declines, the other shares automatically increase. Yet, it is noteworthy that losses in routine employment are not distributed uniformly to both the non-routine manual and the non-routine cognitive employment share.

[18] It bears emphasis that in the context of our analysis, service *occupations* are to be distinguished from the service *sector*: While service occupations, mainly comprise less-skilled personal services, the service sector represents a broad category of industries that can also be highly knowledge-intensive.

Table 2: Occupations in Highest Quintile of the Non-Routine Manual Task Distribution in 1979

Occupation	Log wage	Wage decile	Empl. share low-skilled	Empl. share in overall empl.	Δ Empl. share 1979-2007
Household cleaners until glass, buildings cleaners	3.77	1	71.8	1.90	-0.19
Nursing assistants	4.13	2	29.1	0.53	0.13
Nurses, midwives	4.23	5	1.7	1.18	1.08
Housekeeping managers, attendants	3.77	1	58.8	0.82	-0.15
Other mechanics until watch-, clockmakers	4.29	6	5.9	2.90	-0.05
Others attending on guests	3.77	1	37.1	0.40	-0.12
Doormen, caretakers	4.26	5	26.0	0.46	0.09
Restaurant, inn, bar keepers, waiters, stewards	3.91	1	28.0	0.70	0.51
Factory guards, detectives, watchmen	4.13	2	36.8	0.34	0.16
Building labourer, assistants, n.e.c.	4.04	2	59.2	0.98	-0.52
Motor vehicle drivers	4.28	6	26.3	3.31	-0.01
Railway engine drivers until street attendants	4.31	7	42.6	0.53	-0.09
Locksmiths, sheet metal, plastics fitters	4.33	7	10.3	2.58	-0.54
Steel smiths until pipe, tubing fitters	4.36	8	26.1	0.43	-0.19
Roofers	4.18	4	18.8	0.25	0.02
Sheet metal workers	4.36	7	10.7	0.27	-0.01
Electrical fitters, mechanics	4.29	6	8.1	1.95	-0.06
Carpenters until scaffolders	4.26	6	10.8	0.50	-0.19
Non-medical practitioners, masseurs, physiotherapists	4.18	4	3.4	0.13	0.26
Goods painters, lacquerers	4.26	5	30.3	0.42	-0.11
Street, machinery, container cleaners	4.21	4	65.5	0.33	-0.01
Radio, sound equipment mechanics	4.26	5	16.7	1.05	-0.20
Employment weighted averages					
All	4.18	4.8	25.7	22.0	-0.06
Service Occupations	4.07	3.5	41.3	9.5	0.00
Non-service Occupations	4.27	5.7	13.9	12.5	-0.11

Notes: SIAB Regional File. Shaded fields indicate service occupations following the occupational classification in Blossfeld (1985).

points over the observed period.

As personal service occupations combine low levels of wages and education with high levels of manual task inputs and employment growth, this particular occupational group deserves special attention when investigating the phenomenon of employment polarization. The relevance of employment developments in personal service occupations for employment polarization becomes evident in Figure 3. It illustrates a counterfactual situation of employment growth along the skill distribution between 1989 and 1999 with service employment held constant at its 1989 level. Apparently, employment polarization would have occurred in the counterfactual scenario as well, while the positive growth of employment at the lower tail of the wage distribution is almost exclusively attributable to the growth of personal service occupations. In contrast, developments at the upper tail of the distribution are not related to services.

Having shown that the evolution of personal service employment play a crucial role when investigating employment polarization, we will now analyze whether this growth is related to technological change, as the model by Autor and Dorn (2012) predicts. In order to directly link employment trends to technological change, we will conduct this investigation in the framework of a regression analysis at the level of local labor markets. As we are mainly interested in employment dynamics of low- and medium-skilled employees, we exclude professional occupations that require a university degree or other special training (e.g. engineers, judges or business administrators). While the model proposed by Autor and Dorn (2012) focuses on employment changes of low-skilled labor exclusively, we consider

Table 3: Levels and Changes in Employment Shares by four broad Occupation Categories, 1979 to 2007

	1979	1989	1999	2007	1979-2007	
	Employment share (%)				Change (%pts)	Growth Rate (%)
All						
Professional, Managerial, Technical	14.78	17.18	19.59	20.40	5.62	38.01
Clerical, Sales	22.70	24.28	26.73	27.69	4.99	22.00
Production, Operators	45.13	41.34	33.97	31.90	-13.23	-29.31
Services	17.39	17.20	19.71	20.01	2.62	15.04
Males						
Professional, Managerial, Technical	16.75	18.80	20.75	21.06	4.31	25.75
Clerical, Sales	11.92	12.65	15.42	17.41	5.49	46.05
Production, Operators	54.97	52.76	45.83	43.44	-11.53	-20.97
Services	16.36	15.79	18.00	18.08	1.72	10.53
Females						
Professional, Managerial, Technical	11.02	14.32	17.68	19.30	8.28	75.18
Clerical, Sales	43.30	44.88	45.50	44.73	1.43	3.30
Production, Operators	26.30	21.11	14.28	12.75	-13.55	-51.51
Services	19.38	19.70	22.55	23.22	3.83	19.78

Notes: SIAB Regional File. Sample includes persons aged 20 to 60 living in West Germany. Military and agricultural employment is excluded. Labor supply is measured as the number of days worked in a given year. Part-time work is included and weighted by average working hours according to Dauth (2010).

developments among both low- and medium-skilled workers. This is due to the special nature of the German vocational system, in which there is a vocational degree for the vast majority of existing occupations. Therefore, it is not surprising that the largest fraction of employees in service occupations is medium-skilled (77% in the year 2007), although service occupations also comprise the largest fraction of low-skilled workers among all occupational groups. If we restricted our analysis to low-skilled workers only, we would concentrate on a rather small subset of employees working in service occupations, which is not the purpose of our investigation.

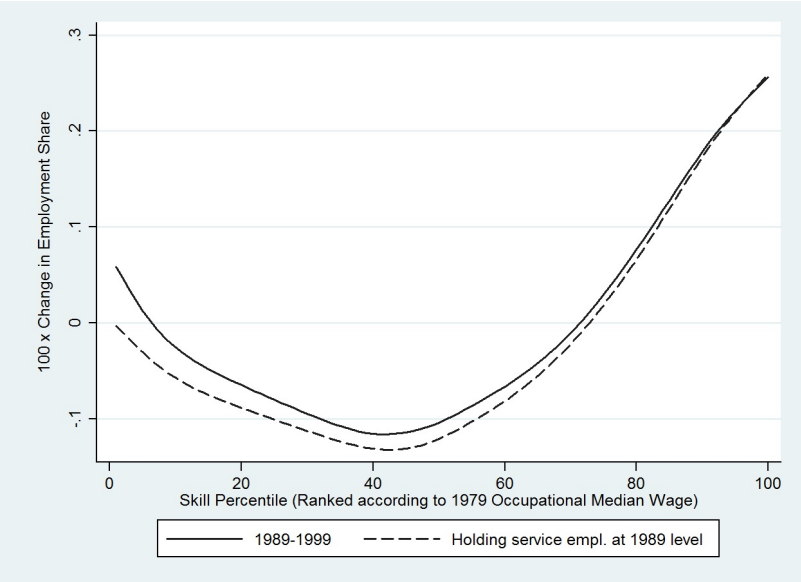
4.2.2 *Baseline Estimates*

If the rising demand for services is indeed a result of technological change, we should see a positive relation between the initial regional routine share and subsequent growth in low- and medium-skilled employment in personal service occupations. A simple OLS regression of the change in the share of service employment in overall employment between 1979 and 2007 on the initial regional routine share yields the following results:

$$SVC_r(1979-2007) = -0.101 + 0.243 \times TSH_r^R(1979) + e_r \quad (t = 2.7) \tag{6}$$

The positive and significant coefficient of 0.243 implies that a region with the mean routine share of 0.537 in 1979 is predicted to increase its share of low- and medium-skilled personal service employment by 2.9 percentage points between 1979 and 2007, which corresponds to the aggregate numbers presented in Table 3. The coefficient is of high economic significance, suggesting that a region at the 85th percentile

Figure 3: Observed and Counterfactual Changes in Employment by Skill Percentile, 1989-1999



Notes: Smoothed changes in employment by skill percentile between 1989 and 1999. Occupations are ranked according to their 1979 median wage using the SIAB Regional File. To construct the counterfactual we keep service employment at its 1989 level. Locally weighted smoothing regression with 100 observations and bandwidth 0.8.

of the routine share distribution will increase its share of personal service employment by 1.0 percentage point more than a region at the 15th percentile over the observed period.

As other local labor market conditions might affect the growth of service sector employment, Panel A of Table 4 provides an overview of different specifications estimating equation 1 with additional explanatory variables. The regression reported in the first column repeats the estimation of the basic equation, additionally including dummy variables for the federal state in which the region is located. In columns 2-7 the model is step-by-step augmented by control variables that may explain differences across regions in the development of personal service employment.

Column 2 includes a measure of population density to control for differences in the urbanity between regions, with the estimate on the routine share being virtually unaltered. Columns 3 to 5 add variables that are expected to influence the demand for personal services. Column 3 includes the fraction of the regional population subject to social security contributions that serves as a proxy for the regional employment rate. According to theory, a higher share of working population should raise the demand for personal services such as restaurant meals or housekeeping, as household production is substituted by market-based production of services. This substitution effect is supported by the positive albeit insignificant coefficient reported in column 3. Along the lines of this argument, the regression is further augmented with the share of female employees which is suspected to be positively related to the growth of service sector employment (Manning, 2004; Mazzolari and Ragusa, 2007). The positive coefficient on the fraction of female employment in column 4 verifies this conjecture and is consistent with the marketization of home production emphasized by Ngai and Pissarides (2008). Column 5 adds the ratio

Table 4: Estimated Impact of the Routine Share on Service Sector Employment

Dep. variable: Δ SVC employment 1979-2007	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				A. Total employment			
Routine Share 1979	0.282***	0.284***	0.271***	0.261***	0.281***	0.257**	0.263**
	(0.095)	(0.096)	(0.100)	(0.099)	(0.102)	(0.101)	(0.104)
Share employed/pop.			0.040	0.070	0.018	0.023	0.045
			(0.064)	(0.060)	(0.068)	(0.066)	(0.066)
Share female/empl.				0.095*			0.086
				(0.051)			(0.053)
High/low skilled empl.					0.135		0.086
					(0.116)		(0.120)
Share foreign empl./empl.						0.048	0.019
						(0.047)	(0.050)
Population density	no	yes	yes	yes	yes	yes	yes
R^2	0.141	0.141	0.143	0.160	0.148	0.147	0.163
				B. Male employment			
Routine Share 1979	0.087	0.047	0.021	0.010	0.043	0.005	0.027
	(0.119)	(0.120)	(0.122)	(0.121)	(0.124)	(0.122)	(0.124)
R^2	0.151	0.164	0.170	0.185	0.186	0.173	0.196
				C. Female employment			
Routine Share 1979	0.631***	0.705***	0.723***	0.712***	0.714***	0.708***	0.685***
	(0.151)	(0.150)	(0.153)	(0.154)	(0.154)	(0.165)	(0.169)
R^2	0.149	0.174	0.175	0.183	0.177	0.177	0.187

Notes: N = 204 labor market regions. All regressions include dummies for the federal state in which the region is located, regional covariates as indicated as well as a constant. Covariates in all Panels are identical and enter with the expected sign. Robust standard errors in parentheses. * Significant at 10%, ** at 5%, *** at 1%.

of high- to low-skilled workers as a measure to reflect formal educational attainment within regions. The positive sign suggests that a higher relative supply of high-skilled workers is related to larger growth of service employment. Yet, the coefficient is not statistically different from zero and hardly alters the point estimate on the regional routine share. Column 6 adds an indicator that potentially influences the supply of services by including the share of the working population that is foreign born. Indeed, the share of foreign employees is positively related to the growth of service employment (Cortes, 2008), but the point estimate is not statistically different from zero and the inclusion leads to a decline of the coefficient on the regional routine intensity. Once we include the full set of covariates in the model (column 7), the estimate on the regional routine share remains robust and still retains 93 percent of the size reported in the base specification in the first column.[19]

So far, we have implicitly assumed that the relation between technological change and the growth of service sector employment is uniform across individuals. Given the steeper increase in service employ-

[19]In order to test the robustness of our results, we repeat the OLS estimation using contemporaneous changes of the regional covariates instead of their 1979 levels. The resulting coefficients presented in Panel A of Table 2 are comparable in magnitude to our prior specifications. Nevertheless, it should be clear that some of these contemporaneous changes are a result of technological change themselves (Autor and Dorn, 2012). We furthermore experimented with different subsamples depending on the size and the region type of the specific labor market. We obtain similar results considering urban or rural regions separately or estimating separate models for large (population>200 T in 1979) and small (population<=200 T in 1979) regions. Results are available from the authors upon request.

ment for female than for male workers, this assumption might not be justified. Furthermore, Black and Spitz-Oener (2010) show that the polarization pressure has been more pronounced for female employees as women have been more exposed to technological change owing to a larger share of days worked in routine intensive occupations. We therefore re-estimate the previous model separately for male and female employees and present the findings in Panels B and C of Table 4. As expected, the results of the two specifications confirm the prediction of differential trends in service employment by gender. For male workers, there is effectively no correlation between the initial routine share of a region and subsequent growth in personal service employment. As opposed to this, the point estimate for females is large and highly significant irrespective of the inclusion of additional covariates. The predicted increase in service employment for the female sample in the region at the 85th percentile of the routine share distribution is 3 percentage points greater than in the 15th percentile region over the observed period, a change that is approximately thrice as large as in the pooled sample.

A considerable part of the workforce employed in service occupations is only marginally employed and therefore not subject to social security contributions.[20] If employment possibilities are mainly created among marginally employed, our results will underestimate the relation between routine intensity and service sector employment growth as our sample lacks information on marginal employment. In order to test for this possibility, we re-estimate the model using data from the German microcensus, a representative one percent sample survey of all persons in private households and community accommodation in Germany. A major advantage of the microcensus is the fact that it entails employment subject to social security contributions as well as marginal employed workers. The results of the baseline estimation (column 1) and the specification including regional covariates (column 2) are depicted in Table 5. Consistent with expectations, the coefficient estimates are slightly larger compared to the results obtained with the SIAB-R, suggesting that additional labor is partly generated among non-standard employment. The point estimate is less precisely measured, which can be ascribed to a much smaller sample size.[21]

The definition of service occupations that we employ in our analysis does not coincide 1:1 with the U.S. census classification adopted by Autor and Dorn (2012), which mainly comprises unskilled personal services. Although a confinement to low-skilled services does not seem appropriate for the German setting, it is still interesting to further narrow down the group of occupations driving the employment changes at the lower tail of the wage distribution. In order to test for differential trends, we further subdivide service occupations into unskilled (all unskilled personal services) and skilled (essentially order and security occupations as well as skilled service occupations) and estimate the employment trends separately for both occupation groups. Results are presented in columns 3 to 6 in Table 5 and reveal a positive and significant relationship between regional routine intensity and the growth of unskilled personal services (columns 3 and 4) and a rather weak association with the growth of more skilled services (columns 5 and 6). This is in line with findings for the U.S. and suggests that the relation between

[20] German law defines employment relationships as "marginal" if individuals work less than 50 days per calendar year or their monthly paycheck does not exceed 400 Euro (mini-job).

[21] A more detailed discussion of the data set and the empirical procedure is provided in the Data Appendix. Due to data availability reasons we have to restrict the analysis based on the microcensus to the years 1982 and 2006. To check the robustness of our baseline results in Table 4, we re-estimate the specification for the change in low- and medium-skilled service sector employment between 1982 and 2006 using the SIAB-R. Results remain virtually unchanged.

Table 5: Estimated Impact of the Routine Share on Service Sector Employment (Microcensus Results)

Dep. variable: Δ SVC	All services		Unskilled services		Skilled services	
employment 1982-2006	(1)	(2)	(3)	(4)	(5)	(6)
Routine Share 1982	0.280*	0.304*	0.287**	0.300**	-0.007	0.004
	(0.148)	(0.156)	(0.139)	(0.147)	(0.071)	(0.077)
Regional covariates	no	yes	no	yes	no	yes
R^2	0.066	0.245	0.084	0.272	0.012	0.059

Notes: $N = 69$ planning districts excluding Northern Schleswig-Holstein and Berlin. The routine share in 1982 is constructed using occupational task information from the BIBB/IAB data in 1979 and regional employment by occupation from the microcensus of 1982. All regressions include regional covariates as indicated as well as a constant. Robust standard errors in parentheses. * Significant at 10%, ** at 5%, *** at 1%.

a region's routine share and subsequent employment growth is more pronounced for unskilled services.

So far, our simple OLS results do not take into account the potential issue of spatial dependency across single labor markets. To address this potential source of bias in the estimates, we re-estimate spatial error models with contiguity and inverse distance weighting and present the results in Panel B of Appendix Table 2. While the contiguity matrix only consists of zeros and ones, the inverse-distance weighting matrix assigns weights that are inversely related to the distance between regions. Distance-based weight matrices are in general better suited to account for spatial dependency among regions than contiguity-based matrices as they describe the regional integration more accurately. However, as the results in Panel B of Table 2 suggest, both weighting methods yield very similar point estimates compared to previous results. Moreover, there is only minor evidence of significant spatial autocorrelation as suggested by the Wald test statistic and the associated p-value.[22]

4.2.3 *Heterogeneity of Effects*

The estimates for overall employment presented in Table 4 suggest a positive relationship between the initial share of regional routine employment and the subsequent growth in service employment, while this relationship is mainly driven by the female workers in our sample. In this section, we allow for more heterogeneity in the adjustment to technological change and re-estimate the main regression separately for different labor market segments. Following the format of earlier equations, all models include the initial routine share and a full set of state dummies, with alternate specifications containing the full set of labor market and demographic controls used above.

We start in Panel A of Table 6 by distinguishing between young (age 20-39) and old (age 40-60) employees. Economic theory suggests that younger workers possess a higher incentive to invest in further education, allowing them to upgrade and reallocate towards high-skill non-routine cognitive rather than low-skill non-routine manual occupations. In contrast, older workers are less likely to invest in further training and are therefore expected to engage in the performance of non-routine manual tasks with a higher probability. Furthermore, recent empirical research has shown that older workers are less likely

[22] As the coefficient estimates in our baseline analysis do not differ from the results obtained from the spatial weighting we are not concerned by the relatively low p-value in columns 1 & 2 that hints at potential spatial correlation.

Table 6: Estimated Impact of the Routine Share by Gender, Age and Working Time

Coefficient on RSH 1979 for labor market segment below	I. All		II. Males		III. Females	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Results by Age						
All Workers	0.282***	0.263***	0.087	0.027	0.631***	0.685***
	(0.095)	(0.104)	(0.119)	(0.124)	(0.159)	(0.169)
Young Workers	0.210	0.156	0.008	-0.107	0.429**	0.483**
(20-39)	(0.129)	(0.137)	(0.149)	(0.156)	(0.205)	(0.224)
Old workers	0.473***	0.457***	0.270*	0.237	1.033***	1.047***
(40-60)	(0.122)	(0.130)	(0.158)	(0.163)	(0.188)	(0.199)
Panel B: Results by Working Time						
All Workers	0.282***	0.263***	0.087	0.027	0.631***	0.685***
	(0.095)	(0.104)	(0.119)	(0.124)	(0.159)	(0.169)
Full-time	0.310***	0.266***	0.089	0.024	0.708***	0.722***
	(0.096)	(0.105)	(0.117)	(0.122)	(0.169)	(0.185)
Part-time	0.833***	0.857***	-0.548	-0.298	0.890***	0.909***
	(0.332)	(0.349)	(1.959)	(2.023)	(0.317)	(0.335)
Regional covariates	no	yes	no	yes	no	yes

Notes: $N = 204$ labor market regions. All regressions include dummies for the federal state in which the region is located, regional covariates as indicated as well as a constant. The covariates enter with the expected sign. Robust standard errors in parentheses. * Significant at 10%, ** at 5%, *** at 1%.

to change occupations towards jobs where new information and computer technologies are prevalent due to skill obsolescence and adaptability problems of older workers (Aubert et al., 2006). As expected, the estimation results indicate that the relation between the initial routine share and subsequent employment growth remains positive for younger workers (columns 1 and 2) but the magnitude decreases significantly, resulting in estimates that are statistically insignificant. Whereas the coefficient for older workers (columns 3 and 4) is highly significant and in line with evidence presented by Autor and Dorn (2009), showing that the decline in routine intensive jobs for older workers is almost entirely absorbed by employment gains in non-routine manual occupations. Estimating the model separately by gender reveals distinct patterns for male and female workers. Interestingly, the results for male workers suggest that there are heterogeneous developments for young and older employees. Similar to the results for the entire male sample, there is no evidence for a significant correlation between a region's routine intensity and the subsequent growth of service employment for young males. Yet, for older workers, the coefficient is positive and sizeable, although the significance level further decreases with the inclusion of additional control variables. In line with our earlier findings, the age specific results are mainly driven by the female workers in our sample, while the magnitude of the coefficient is more than twice as large for older women than for young ones.

In Panel B of Table 6 we distinguish the effects by working-time. Studies have shown that the fraction of part-time employees in the service sector is particularly high (Houseman, 1995).[23] In order to test whether there have been different employment trends for full- and part-time employment, we estimate

[23] A report by the European Foundation for the Improvement of Living and Working Conditions (2007) emphasizes the importance of part-time employment for overall employment changes.

models for both employment types separately and present the regression for the entire sample as well as for male and female employees. The results for the pooled sample (columns 1 and 2) suggest that the relationship between routine intensity and the growth of service employment is positive and statistically significant for both employment types, although the magnitude of the coefficient is approximately three times larger for part-time than for full-time employment. Comparing the increase in service employment for the sample of part-time workers in a region at the 85th percentile with a region at the 15th percentile of the routine share distribution, the coefficient of 0.897 suggests a differential increase in the share of service employment of 3.6 percentage points between 1979 and 2007. Again, columns 3-6 reveal that this result is mainly driven by employment gains in both full-time and part-time jobs realized by female workers. However, due to very small sample sizes especially for the sample of male part-time workers, the coefficients are only imprecisely measured as can be seen by the particularly large standard errors.

All things considered, our results suggest that the importance of the relationship between the measure of routine intensity and changes in the employment share of service occupations differs substantially across subsets of overall regional employment. The polarization of employment seems to be mainly driven by the female workers in the sample and is even more pronounced for part-time working and older women.

4.3 Unemployment and Migration

So far, our empirical findings on changes in service sector employment related to technological progress confirm findings for the U.S. by Autor and Dorn (2012) and for Germany as presented by e.g. Spitz-Oener (2006) and Dustmann et al. (2009). However, the overall phenomenon of service sector growth is somewhat less pronounced in Germany than in the U.S., although computerization should have had comparable implications in both countries alike. Rising demand for services in Germany is likely to be depressed by higher payroll taxes, resulting in more home-based than market based production (Freeman et al., 2005; Burda et al., 2007). This argument is in line with several other studies, which document that many European countries seem to be "missing" personal services such as retail trade or hotel and restaurant employment (Piketty, 1997). Furthermore, the supply of services might be suppressed by product market regulation and a far more generous unemployment benefit system in Germany compared to the United States.

We test for the latter hypothesis by exploring the relationship between the initial routine share and subsequent changes in the regional unemployment rate. The Statistics Department of the German Federal Employment Agency (Bundesagentur für Arbeit, BA) publishes a time series on district level data on the unemployment rate starting in late 1984. Unfortunately, further splits by age groups and gender are only available at the district level from 1998 onwards. In order to construct unemployment rates for the entire sample as well as for men and women separately, we therefore use data on benefit recipients available in the SIAB-R to compute regional unemployment rates between 1981 and 2004.[24] For reasons of comparability, Panel A of Table 7 depicts the results of our baseline regression for the comparable shorter time period from 1981-2004. The coefficient estimates are similar in magnitude and significance

[24] See the Data Appendix for details on the construction of the unemployment rate, reasons for the shorter time period and robustness checks.

to our previous results for the longer time span 1979-2007.

Panel B reports the results for the analogous regression with the change in the district level unemployment rate as dependent variable. In line with expectations, the baseline specification presented including the regional routine share and state dummies as explanatory variables predicts a differential increase in the unemployment rate in regions that were initially routine intensive. With the inclusion of additional covariates (column 2), the magnitude of the point estimate declines by about half of its size but remains statistically significant at the 10% significance level. When comparing a region at the 85th percentile of the routine share distribution with a region at the 15th percentile, the coefficient of 0.135 implies that the unemployment rate differentially increased by 0.58 percentage points between 1981 and 2004. In the remaining columns of Panel B, we repeat the regressions separately for males and females. Given our results for personal service employment, which is almost entirely driven by female employees, we would expect the increase in the regional unemployment rate to be larger for men that for women. Yet, this prediction is not born out by the data. The results for male employees in columns 3 and 4 indicate a positive albeit insignificant correlation between the initial routine share and the subsequent change in the regional unemployment rate. In contrast, the change in the unemployment rate of women is positive, statistically significant and significantly larger than the coefficient estimate for the male counterpart.[25]

Table 7: Estimated Impact of the Routine Share on Regional Unemployment and Net Migration

	I. All		II. Males		III. Females	
	(1)	(2)	(3)	(4)	(5)	(6)
			A: Δ Service employment 1981-2004			
Routine Share 1979	0.239***	0.236**	0.109	0.063	0.483***	0.546***
	(0.089)	(0.096)	(0.108)	(0.123)	(0.151)	(0.159)
R^2	0.145	0.154	0.162	0.212	0.087	0.123
			B: Δ Unemployment rate 1981-2004			
Routine Share 1979	0.226***	0.135*	0.172*	0.102	0.258***	0.152*
	(0.070)	(0.071)	(0.090)	(0.084)	(0.078)	(0.081)
R^2	0.338	0.457	0.368	0.475	0.182	0.300
			C: Δ Net migration Share 1979-2007			
Routine Share 1979	-0.049	-0.067	-0.077	-0.097*	-0.009	-0.023
	(0.040)	(0.042)	(0.051)	(0.053)	(0.050)	(0.055)
R^2	0.043	0.082	0.051	0.080	0.01	0.03
Regional covariates	no	yes	no	yes	no	yes

Notes: $N = 204$ labor market regions. All regressions include dummies for the federal state in which the region is located, regional covariates as indicated as well as a constant. Robust standard errors in parentheses. * Significant at 10%, ** at 5%, *** at 1%.

[25] With our approach of calculating unemployment rates, we would be furthermore able to consider differences by age groups. However, due to rather small numbers of observations, upon which the aggregate numbers rely, the explanatory power of these regressions is limited. Results are available from the authors.

So far, we have not taken into account that the composition of local labor markets might have changed over time and thereby implicitly assumed that labor is immobile across regions. To test whether this assumption is appropriate, we analyze if technological change induced a reallocation of employees towards regions that are less affected by computerization. Unfortunately, official data on the number of inward- and outward-migrants on the regional level separately for males and females is not fully available since 1979. Therefore, we use the regional information in the SIAB-R to compute the regional out- and inmigration shares for the years 1979 and 2007. In this context, migration is defined as a job change, when the new job is in a different labor market than the previous one. As our definition builds upon job changes and not simply changes of the place of residence, it fits well the purpose of our analysis. However, in order to validate the robustness of our results, we compare our migration shares to the official data on migration flows released by the Federal Statistical Office. Further details are discussed in the Data Appendix.

Panel C of Table 7 presents regression results of the change in the net migration share of low- and medium-skilled employees between 1979 and 2007 on the initial regional routine share. The negative coefficients in columns 1 and 2 suggest that regions that were prone to technological change experienced higher outward-migration for the entire population, although we cannot reject the null hypothesis that this relation is different from zero. For the male subsample (columns 3 and 4), the coefficient is negative and, once the control variables are included, significant at the 10% level. In contrast, the estimated coefficients for female employees in columns 5 and 6 reveal that there is no correlation between a region's initial routine share and subsequent migration patterns. Our finding is in line with existing literature on regional adjustments to labor market shocks, which has found that responses in regional mobility are relatively slow and incomplete, particularly among less-educated workers (Topel, 1986; Blanchard and Katz, 1992; Glaeser and Gyourko, 2005; Notowidigdo, 2011; Bound and Holzer, 2000). Furthermore, it has been shown that internal migration in Europe is much lower than in the US (Decressin and Fatàs, 1995; Nahuis and Parikh, 2002) and that adjustment processes to shocks occur via lower participation rates.[26]

4.4 Regional Wage Inequality

So far, we have documented that German local labor markets differentially experienced employment polarization depending on their initial routine employment share. In this section, we address the question whether the observed employment polarization is accompanied by wage trends in the same direction. Given the mapping between the specific tasks and their location on the wage distribution, the expected changes in the relative task prices should translate into a polarization of earnings. Wages paid to routine tasks will decline as information technology becomes more affordable, since computer capital perfectly substitutes for routine labor. Due to q-complementarity between abstract and routine tasks, the wages of high-skilled workers will rise, resulting in increasing upper-tail wage inequality. If goods and services are weekly complementary, wages paid to low-skilled manual labor rise relative to wages for routine tasks, eventually compressing lower-tail inequality.

[26] One explanation for this pattern is given by cross-country differences in the unemployment compensation and welfare system which may explain higher barriers to mobility in European countries compared to the U.S. (Arntz and Wilke, 2009; Arntz et al., 2007). Higher compensation may reduce the potential return to migration and thereby suppress mobility.

We measure upper tail, lower tail and overall wage inequality by the P85/P50, P50/P15 and P85/P15 log daily wage ratio for full-time workers, respectively. Panel D of Table 8 summarizes the evolution of the three measures over time. The aggregate numbers suggest that overall wage inequality remained relatively stable until the 90's, but rose steeply thereafter. Upper tail wage inequality grew constantly and moderately over the observed period, while lower tail wage inequality was relatively stable during the 80's and increased thereafter. Thus, the steep rise in overall wage inequality is mainly driven by increasing lower wage inequality, indicating that economy-wide wage developments at the upper tail of the distribution are in line with the polarization hypothesis, while the wage structure at the lower tail of the distribution has diverged rather than becoming more compressed.

Table 8: Estimated Impact of Routine Share on Regional Wage Inequality

	I. All		II. Males		III. Females	
	(1)	(2)	(3)	(4)	(5)	(6)
	A: Δ P85-P15 (Overall Wage Inequality)					
Routine Share 1979	0.221*	0.104	0.371***	0.209*	-0.059	-0.092
	(0.132)	(0.121)	(0.119)	(0.110)	(0.156)	(0.151)
R^2	0.083	0.353	0.092	0.434	0.100	0.152
	B: Δ P85-P50 (Upper Tail Wage Inequality)					
Routine Share 1979	0.053	0.026	0.096*	0.044	0.008	0.014
	(0.052)	(0.049)	(0.055)	(0.052)	(0.071)	(0.075)
R^2	0.049	0.206	0.081	0.269	0.035	0.053
	C: Δ P50-P15 (Lower Tail Wage Inequality)					
Routine Share 1979	0.148	0.070	0.240***	0.148*	-0.062	-0.100
	(0.090)	(0.087)	(0.080)	(0.080)	(0.112)	(0.113)
R^2	0.139	0.320	0.110	0.342	0.176	0.238
Regional covariates	no	yes	no	yes	no	yes

D. Summary Statistics Wage Inequality Measures

	1979	1989	1999	2007
Average Log Real Wage	4.134	4.226	4.266	4.247
	(0.078)	(0.085)	(0.084)	(0.100)
P85/P15 Wage Ratio	1.196	1.201	1.226	1.271
	(0.020)	(0.021)	(0.029)	(0.034)
P85/P50 Wage Ratio	1.077	1.082	1.089	1.105
	(0.009)	(0.012)	(0.015)	(0.015)
P50/P15 Wage Ratio	1.110	1.110	1.126	1.150
	(0.016)	(0.015)	(0.017)	(0.020)

Notes: N = 204 labor market regions. All regressions include dummies for the federal state in which the region is located, regional covariates as indicated as well as a constant. The covariates enter with the expected sign. Robust standard errors in parentheses. * Significant at 10%, ** at 5%, *** at 1%. Panel D shows means and standard devioations in parantheses.

To explore the relationship between the evolution in wage inequality and regional routine intensity in more detail, we estimate variants of equation 1 of the change in the respective log wage ratio between

1979 and 2007 for each measure of wage inequality. Following the format of earlier estimations, all models include the initial routine share and a full set of state dummies, with alternate specifications containing the full set of labor market and demographic controls used before. The estimates for the pooled sample are depicted in columns 1 and 2 of Table 8. The results suggest that overall wage inequality (Panel A) has grown more in regions that have a high initial routine share, although the coefficient becomes insignificant with the inclusion of additional control variables. This differential rise in overall inequality is driven both by increasing upper tail inequality (Panel B) as well as increasing lower tail inequality (Panel C).

As we have argued before, the assumption that different labor market segments are affected equally has proven implausible. We therefore re-estimate the model separately for male (column 3 and 4) and female (column 5 and 6) employees. Indeed, the results for the different subsamples reveal distinct wage developments. For male employees, overall wage inequality has significantly increased in regions with a higher routine share over the observed period. This increase in mainly driven by differential increases in lower tail inequality (Panel C), which contradicts findings for the U.S. (Autor and Dorn, 2009). In contrast to the results for the male sample, overall wage inequality for women has declined in regions with a high routine share (Panel A, columns 5 and 6). When analyzing developments at both tails separately, it becomes evident that this stems from a differential increase in upper tail inequality (Panel B), which is offset by a relatively larger decline in lower tail inequality (Panel C). Although none of the results are statistically significant at conventional significance levels, it deserves notice that wages for both subgroups follow distinct patterns and wage dynamics for females mirror the respective employment trends.[27]

Our results show that despite significant changes on the quantity side of the labor market, the rise in employment has not come along with significant accordant wage adjustments. This can occur if goods produced by routine labor and services produced by non-routine manual labor are not complementary. Then, the demand for services might not rise sufficiently to overcompensate increases in the supply, leaving wages relatively unchanged. Our results at the regional level are consistent with existing studies on aggregate wage trends in Germany, which do not find evidence of wage polarization at the lower tail of the wage distribution (Dustmann et al., 2009; Antonczyk et al., 2009).

5 Conclusion

This paper examines the dynamic patterns of employment and wage polarization in Germany in recent decades at the level of local labor markets. We build on concepts of the task-based view of technological progress, according to which technological change favors labor market outcomes at the lower as well as at the upper tail of the wage distribution relative to the middle. In order to test the predictions of the task-based framework, we directly relate employment outcomes to technological change by exploiting regional variation in the "computerizability", that is a region's potential to be affected by technological change.

Our results suggest that the variation in the routine share across regions has indeed explanatory

[27] We also conducted the analysis by different age groups and gender. However, these results do not yield additional insights and are therefore not reported here. Results are available from the authors upon request.

power for subsequent employment changes. Regions that were initially specialized in routine tasks adopted information technology faster and witnessed a larger displacement of routine employment. At the same time, these regions experienced a differential growth of occupations in which non-routine manual tasks are prevalent. We show that among these occupations, particularly the growth of the personal service sector contributed to the twisting of the lower tail of the employment distribution. Our results indicate that the growth of service employment in initially routine intensive regions is most pronounced for women and older workers. Furthermore, there is a substantial difference in the magnitude of the relationship for full-time versus part-time employment.

When comparing recent employment trends in Germany to developments in the U.S., we find that task requirements and employment patterns have evolved very similarly in both countries, especially during the 1990's. Yet, we show that the relationship between technological change and the growth of service sector employment is smaller in magnitude in Germany than in the United States. We argue that this can partly be attributed to the generous unemployment benefit system in Germany, as we find evidence that the unemployment rate differentially increased in routine-intensive local labor markets. We also investigated the possibility of interregional mobility as a response to technological change but find no robust support for adjustments along that margin. In sum, our study has shown that the task-based framework is well suited to explain recent changes in the employment structure in West Germany. The question now arises, why similar developments in task requirements and employment are not accompanied by accordant changes in the wage structure.

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A Data Appendix

A.1 Replication using the German Microcensus

The microcensus is a representative one percent sample survey of all persons in private households and community accommodation in Germany provided by the Federal Statistical Office and covers approximately 370,000 households with 800,000 individuals. It has been collected for West Germany since 1957 and extended to the new Federal States in 1991. In 2005 the survey design changed from data collection during a fixed reference week (usually the last holiday-free week in April) to a continuous survey design. It contains detailed information on the demographical background (age, sex, nationality etc.), the labor market status (employment status, employment characteristics, job search), education and training, income and the household and family context (children, living conditions).

A major drawback of the data is the limited availability of regional information due to data security regulation. As a result, the microcensus only provides information on the level of 97 German planning districts (Raumordnungsregionen, ROR) that are defined according to commuting ranges and comprise labor market regions that are relatively self-contained. A reallocation of districts in 1996 resulted in a new assignment of planning districts and unfortunately, the statistical office does not provide a time consistent definition of this regional classification. As a result, we need to group some ROR's together in order to ensure comparability over time. In addition, we exclude the region "Northern Schleswig-Holstein" from our regressions as its routine share is more than one standard deviation larger compared to the second largest regional routine share. Out of the 74 ROR in West Germany we are than left with 69 planning districts excluding Berlin.

Due to data availability reasons we have to restrict our analysis to the years 1982 and 2006. To construct the regional routine share on the level of planning districts, we use the occupational task information from the 1979 BIBB/IAB wave and weight it with regional employment in 1982 using the detailed occupational employment information entailed in the microcensus. We restrict our sample to the West German civil labor force population from the age of 20 to 60 excluding agricultural and public sector employment. Labor supply is measured as the number of hours worked and includes full-time and part-time employment as well as marginally employed workers. We then relate the growth in low- and medium-skilled service employment between 1982 and 2006 to the initial regional routine intensity in 1982 and present the results in Table 5. To make the results comparable we include a similar set of regional covariates and are furthermore able to include the elderly share of population (> 65 years) which is considered to be a potential demand shifter. Most covariates enter with the expected sign: positive for fraction of high to low and medium skilled, share of foreign employees, female labor force participation, elderly share of population but negative for the share of working population. However, the coefficient estimates are not individually significant in the specification including all regional covariates and are not tabulated in Table 5 to conserve space. The detailed occupational classification in the microcensus allows us to further subdivide service occupations into unskilled (all unskilled personal services) and skilled (essentially order and security occupations as well as skilled service occupations) services.

A.2 Computing Regional Unemployment and Migration Rates using SIAB-R

For the construction of regional unemployment rates separately by gender we rely on the benefit recipient history included in the SIAB-R, which provides information on periods during which individuals receive earnings-replacement benefits (unemployment benefit, unemployment assistance and maintenance allowance) from the Federal Employment Agency (Bundesagentur für Arbeit, BA). Due to data limitations we are forced to conduct our analysis on unemployment responses for the shorter time period 1981 to 2004. On the early end we are limited because the benefit receipt data up to and including 1980 are only partially recorded (Dorner et al., 2011). A change in legislation in 2005 limits a consistent analysis of unemployment trends after this year.

We measure the regional unemployment rate as the sum of days residents were registered as unemployed relative to total days worked in a given year and a given region. To validate the robustness of our results, we compare our self-computed unemployment rate with administrative records provided by the Statistics Department of the German BA that publishes a time series on district level data on the overall unemployment rate starting in late 1984. With the data stemming from the SIAB-R, we are restricted to unemployment information of workers who were previously employed subject to social security contributions. However, both measures are highly correlated in the years after 1985, with the correlation coefficient varying between 0.85 and 0.92. In addition, we regress the change in the unemployment rate for the pooled sample between 1985 and 2004 (were we have reliable data from both sources) on the routine share in 1979 using both definitions of the unemployment rate. We obtain similar coefficients from both specifications although the difference is not statistically significant.

We construct migration shares using information on the workplace location available in the SIAB-R. Total regional inmigration is defined as the sum of workers, who have changed job from some region into a certain region. Analogously, total outmigration is defined as the sum of workers in one region, who have changed their jobs towards a workplace that is located in a different region. In order to check the robustness of our results, we compare the self-computed migration shares to the available official data on migration flows published by the Federal Statistical Office. The correlation coefficient for the in- and outmigration measures varies between 0.92 and 0.94.

B Table Appendix

Table 1: Descriptive statistics for regions, 1979

Full-time employment	40,610
	(60,442)
Routine share measure	0.537
	(0.019)
PC Share	0.050
	(0.010)
Fraction female employees	0.330
	(0.045)
Fraction high to low and medium skilled employees	0.030
	(0.016)
Fraction foreign employees	0.081
	(0.048)
Fraction employed	0.125
	(0.033)
Population density	301
	(418)
Average region population	297,494
	(376,437)
Number of regions	204

Notes: All fractions are computed with respect to total full-time employment for a given region.

Table 2: Estimated impact of routine task intensity on regional service sector employment: Robustness checks

	I. Alternative classification		II. Spatial Error Weighting Matrices			
	Cov. in cont. changes		Inverse Distance		Contiguity	
Dependent variable:						
Δ SVC employment 1979-2007	(1)	(2)	(3)	(4)	(5)	(6)
Routine Share 1979	0.282***	0.289***	0.303***	0.288***	0.288***	0.270***
	(0.095)	(0.100)	(0.092)	(0.100)	(0.091)	(0.100)
Regional covariates	no	yes	no	yes	no	yes
R^2	0.141	0.152				
Wald-Test			5.663	5.379	0.391	0.264
p-value			(0.017)	(0.020)	(0.532)	(0.607)

Notes: $N = 204$ labor market regions. All regressions include dummies for the federal state in which the region is located, regional covariates as indicated as well as a constant. The covariates enter with the expected sign. Robust standard errors in parentheses. * Significant at 10%, ** at 5%, *** at 1%.

Table 3: Estimated impact of routine task intensity on regional service sector employment: Robustness checks

	I. Baseline	II. Alternative RSH Measure			III. Stacked 1st diff.
Occupations used for construction of RSH:	all	50% most routine	33% most routine	25% most routine	all
Dependent variable: Δ SVC employment 1979-2007	(1)	(2)	(3)	(4)	(5)
		A. OLS estimates			
Routine Share 1979	0.282***	0.132***	0.125**	0.208***	0.096**
	(0.095)	(0.046)	(0.051)	(0.055)	(.043)
R^2	0.141	0.141	0.128	0.169	0.326
N	204	204	204	204	612
	B. Effect Size: Region at 85th vs 15th percentile of RSH measure				
P85-P15	0.043	0.083	0.076	0.061	0.043
Effect Size	1.213	1.096	0.950	1.269	1.156

Notes: $N = 204$ labor market regions. All regressions include dummies for the federal state in which the region is located. For ease of exposition, column 1 repeats the baseline estimates. Column 5 displays the results of a stacked first differences regression that additionally includes time dummies. Robust standard errors in parentheses. * Significant at 10%, ** at 5%, *** at 1%.

C Figure Appendix

Figure 1: Distribution of routine share 1979