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by

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

Ipsita Roy^{*} and Davide Consoli

Abstract

Building on the canonical model of skill-biased technical change to incorporate differential effects of technology and international trade on the skill composition of occupations, the paper employs a task-based approach to analyze structural changes in regional employment within a rich vocational education setting in West Germany during 1979 and 2012. Results confirm theoretical predictions that regional employment districts with high initial share of routine occupations have experienced greater subsequent adoption of computer and information technology and larger decline in routine occupations. Exposure to global imports in goods and services have reduced overall employment in routine-intensive occupations; the magnitude being notably smaller as compared to technology. However, when looking at the direction of displacement of routine-workers, regions with greater share of routine jobs have experienced greater growth of high-skilled abstract jobs in the subsequent periods while the overlap between initial apprenticeship intensity and subsequent decline in regional routine employment is significantly strong. Taken together, findings show that unlike in the U.S. where employment growth in low-skilled service occupations has been the greatest, in Germany there is a greater trend towards occupational upgrading and larger growth in managerial and professional occupations due to the operationalization of its apprenticeship system.

Keywords: Skill-biased Technical Change, Task-based Approach, Skill Composition, Technology, International Trade, Apprenticeship, Regional Employment Districts

JEL Classification: E24, F16, J21, J24, O33, R23

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1 Introduction

The role of technology in shaping employment pattern in industrialized countries around the world continues to be a topic of major debate. Labor economists have traditionally considered technology to increase the productivity of and accelerate the demand for high skill workers. This idea is the basic foundation of the so-called skill biased technical change (SBTC) hypothesis, that is, the expectation that the complementarity between technologies and human capital favours high skilled workers to the detriment of low skilled ones (Goldin and Katz 2009). Empirical evidence on the United States during the 1980s and more recently on Great Britain and Europe (Levy and Murnane 1992, Katz and Murphy 1992, Krueger 1992) confirms increased employment for technology-intensive high-skilled occupations and substantial displacement of low-skilled manufacturing occupations due to substitution by capital in the form of computers and automated machinery. Similar trends were also observed in college wage premia, with substantial increases in the wages of college-educated workers relative to that of high-school graduates (Katz and Murphy 1992, Card and DiNardo 2002).

While SBTC provides an important explanation for the increase in the relative supply of high-skilled labor coupled with rising wage inequality in the U.S labor market throughout the 1970s and 1980s, the tenet has come under closer scrutiny in recent years. On a conceptual level it has been pointed out that the mono-dimensional portrayal of skills underpinning SBTC neglects that workers perform a variety of workplace 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 tasks (Acemolgu and Autor 2012). A second weakness concerns the inability of the SBTC hypothesis to accommodate recent empirical evidence on the phenomenon on employment polarization, in particular, fast growth of high-skilled as well as 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 SBTC conjecture that an increase of capital intensity favors "monotonically" workers with higher levels of skills has been decisively refuted (Autor, Levy and Murnane 2003, Goldin and Katz 2009, Acemoglu and Autor 2012).

From these critiques, stems a burgeoning literature on the relation between technology and labor, and on the determinants of employment polarization. Two explanations stand out. The first is that ICT is a substitute for human labor in 'routine' tasks that are the core of middle-skill occupations such as clerical jobs (Autor et al. 2003, Goos and Manning 2007). However, technological progress complements 'non-routine' tasks that form the basis of high-skill abstract occupations such as research and development, but is neutral towards non-routine menial jobs that have a high manual content such as personal services. Taken together, these processes yield a "non-monotonic" growth of employment by skill level at the upper and lower tail of the distribution with an increase in their relative demand, and the hollowing out of the middle part of the distribution. The second explanation refers to the effects of globalization and, in particular, to job outsourcing and trade competition from China and India which have been observed to be 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). Trade with less developed and developing countries gives access to cheap labor and provides greater scope for offshoring of procedural routine-intensive tasks that require minimum complexity, thereby reducing the relative demand and wages for such occupations on the domestic front. Furthermore, import competition on the global level affects quality-improvement decisions of domestic producers and subsequently increases the relative demand for non-routine skills. 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 "taskbased model" (Autor, Levy and Murnane 2003, Spitz-Oener 2006) accommodates crucial findings of labor market changes due to the diffusion of technology and the imbalances brought about by international trade, and forms the first building block of the current study.

In spite of widespread consensus on the role of these global forces in shaping employment pattern in industrialized economies, 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 demographic, sectoral, regional and socio-economic factors to productivity growth and competitiveness is contingent to the particular circumstances of the attendant local economy. Consequently, there is demand for countryspecific evidence that can elucidate the extent to which the changes triggered by technology and trade are amplified or hampered by regional characteristics, sectoral shifts in occupational composition and local institutions. The literature has so far concentrated on the case of the US (Autor and Dorn, 2013) and there is a lack of empirical evidence on other areas of the world economy. The present study takes the cue from this backdrop and proposes an empirical analysis of the structural changes in the employment structure of West Germany during the period 1979-2012. The main focus is on the dynamics of employment agency districts, that is, on harmonized territorial units identifiable on the basis of recruitment offices, and underlying educational settings such as apprenticeship system, changing consumer preferences and subsequent growth of low-skilled service occupations in explaining employment polarization. Accordingly, the project builds on and contributes to existing literature on job polarization by: (i) dis-entangling employment dynamics across employment agency districts in West Germany using task-based approach, rather than examining aggregate trends on a macro-level; (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) exploring the validity of "reallocation effect" and growth of non-college service occupations in the context of Germany, as recently documented in the U.S. labor markets; and, (iv) investigating the effect of institutional factors such as apprenticeship training on such regional employment structure.

The rest of the chapter is organized as follows: Section 2 provides the conceptual background and a review of existing literature. Section 3 presents the data sources, construction of relevant measures and the empirical strategy applied. Section 4 summarizes the main findings and Section 5 concludes the chapter with policy implications and steps for future research.

2 Background and Related Literature

2.1 The Task-based Approach

The starting point of the current study is the recognition that the effect of technological change on occupational groups, and hence skill requirements, is not uniform across the skill distribution as traditionally considered. Prior research (Autor et al. 1998, Berman et al. 1998, Acemoglu 1998) on skill biased technical change advocates that adoption of new technologies and computerization at workplace increased the productivity of more-educated workers and reduced the relative demand for routine-based workers. In other words, skill-complementary technology increased the demand for "high skilled" college-graduates relative to "low skilled" high-school graduates giving rise to the phenomenon of wage inequality and unemployment in the U.S. labor markets in the 1970s. Subsequently, the canonical model (Tinbergen 1974, 1975, Katz and Murphy 1992, Goldin and Katz 2009) provided considerable theoretical and empirical applicability in disentangling the effect of ICT on two distinct and imperfectly substitutable skill groups, and explained early labor market trends in industrialized countries.

Nonetheless, recent evidence (Autor et al. 2003) on the changing employment pattern in the U.S. has pointed towards some major shortcomings and limited validity of the canonical model. First, the model considers standard measures for occupations and skill requirements such as high-skilled and low-skilled workers, share of college-educated and high-school graduates in total employment, share of white and blue collar workers, without distinguishing between tasks and skills. Given that a particular occupation consists of several workplace tasks that a worker performs, it is expected that new technology exerts a 'selection effect' on some job activities (tasks) and on the associated know-how (skills), rather than on the entire vector of occupational tasks. Accordingly, it is crucial to understand how skills are assigned to a particular task and how this allocation of skills is affected by ICT (Autor et al. 2003, Spitz-Oener 2006). Second, the canonical model fails to account for the non-monotonic shifts in employment and wage patterns observed in the U.S. labor markets during the early 1990s. Consistent with the SBTC hypothesis, while job opportunities and earnings increased for the top third of the skill (wage) distribution and decreased in the middle, no such occurrence was observed at the lowest tail of the distribution, thus refuting the SBTC theory. In fact, share of employment in the lowest third typically consisting of low-skilled manual and service occupations, continued to grow. This "polarization" of employment and return to skills across occupations therefore pointed not only towards changes in the skill content of occupations, but also highlighted the need to additionally consider changes with respect to within-occupational task composition.

On this basis, the current study focuses on the "task-based approach" proposed by Autor, Levy and Murnane (henceforth ALM, 2003) as an appealing conceptual framework for the study of structural changes in the workforce in German employment districts during the last three decades. The central theme of the task-based approach is that occupations differ in their task composition and therefore in the relative importance of abstract, routine and non-routine manual skill demands. For what concerns technology, machines perform better physical and cognitive 'routine' tasks which can be codified in the form of instructions while humans retain a cognitive comparative advantage at 'non-routine' activities that involve complex pattern recognition. Ideally, the task-based approach 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, clerical and office-related activities, quality control, measuring and monitoring machine operation; and routine physical activities such as controlling machines and processes, operating vehicles and devices, sorting items. Second, computer capital is complementary to occupations that involve highly complex "non-routine tasks" such as problem-solving, analytical and interactive skills. Examples of such tasks are scientific research, making managerial and administrative decisions, creative thinking, providing consultation and advice to clients, resolving conflicts, mediating negotiations, and training and educating others. Last but not least, 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, drivers and security guards, unskilled medical and health-care personnel, house-cleaners and other menial laborers. Given this framework, it can be argued that the task-based approach allows for a more flexible interpretation of the relation between labor and capital in performing job tasks, and is especially relevant in those contexts in which technology plays a dual role, partly complementing and partly substituting human work (Autor 2013). Furthermore, this approach has demonstrated a better explanatory power also for the analysis of the impact of trade on employment structure (Acemoglu and Autor 2012, Autor and Dorn 2013).

To provide a clearer picture of the analytical framework employed in the study, let us begin with some descriptive evidence. Figure 1 plots the percentage point changes in employment shares of nine major occupational groups throughout 1979-2012 in Germany using the task-based approach. Herein occupations are grouped across the skill distribution in an ascending order and correspond to manual, routine and abstract taskcontents at the start of the period, that is, 1979. 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 polarization pattern in employment arises given an increase in the share of low-skilled service occupations and high-skilled abstract occupations.

A number of recent empirical studies adopt the task-based approach to analyze the interplay between technological progress and changes in task-composition of occupations in relation to structural changes in the employment structure of Germany (Spitz-Oener 2006, Antonczyk et al. 2009, Senftleben and Wielandt 2013, Rendall and Weiss 2014). Spitz-Oener (2006) builds upon the task-based model of ALM and examines the effect of ICT on within-occupational skill requirements. Using data on occupational-level for West Germany during 1979-1998, author finds that skill requirements of occupations have changed drastically since the early 1980s. Jobs have become more complex today, in the sense that abstract/cognitive task-content of occupations have increased while share of routine tasks has significantly dropped. However, most of the task-changes have occurred within occupations that are mostly affected by automation and adoption of new technologies, while no such effect is found with respect to changes in educational attainment



Figure 1: Employment Pattern in Germany (1979-2012)

or gender composition. Antonczyk et al. (2009) analyze the empirical applicability of the task-based approach for understanding evolution of the German wage structure during 1999-2006, and present interesting findings. Following significant differences in the pattern of wage inequality among full-time male employees in German labor markets as compared to those in U.S. based studies, authors perform a Blinder-Oaxaca type decomposition of changes in the wage distribution for the entire time period. Results provide evidence on the interplay of personal characteristics and allocation of tasks in explaining recent increase in wage inequality in Germany, subsequently pointing towards considering other factors such as unionization and labor market reforms to study wage patterns in Germany. On this basis, later studies by Senftleben and Wielandt (2012) and Rendall and Weiss (2014) consider variations in regional task- and educational-composition to analyze effects of technology on employment in Germany during 1979-2007. Consistent with the findings of Autor and Dorn (2013) for the U.S., authors find routine-intensive labor markets to be most affected by technological change in terms of increased adoption of computers at workplace, reduced employment in routine-intensive occupations and increased reallocation towards low skilled non-routine employment. However, significant differences in polarization pattern is found between apprentices and non-apprentices, with no polarization observed when considering apprentice workers while a polarizing pattern of employment observed for non-apprentice workers.

2.2 International Trade

The debate on employment polarization 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 U.S. 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 facilitates 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

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that require intensive use of non-routine tasks (Verhoogen 2008).

The recent study by David, Dorn and Hanson (2013) on the incidence of technology and trade across local labor markets in the U.S. 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 one hand, trade-exposed labor markets (commuting zones or CZs in the U.S.) 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-taskintensive 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 and sectoral variations in employment and wage patterns.

Akomack et al. (2013) analyze the extent of employment polarization due to adoption of ICT and offshoring in the United Kingdom between 1997 and 2006. Distinguishing between task-composition within and between occupations, authors find that SBTC and institutional settings (unionization) significantly determine changes in task-content of workplace jobs while no effect is found with respect to offshoring. On the contrary, employment changes between occupations exhibit a polarization pattern, that is, an increase in the relative demand for high-skilled non-routine occupations accompanied by gradual erosion of routine employment in the middle of the skill distribution and by rising employment in low-skilled non-routine service occupations. Overall ICT has a stronger effect on polarization than offshoring. Goos et al. (2009), in a cross-country analysis on 16 European countries during 1993-2006, examine the role of technology, globalization, institutions and product demand effects to explain recent shifts in employment patterns. Confirming the results of ALM, authors find that routinization is the most important contributor of job polarization while offshoring, changes in wage-setting regulations and product demand play relatively smaller role in explaining employment trends in Europe.

Looking closely at Germany with respect to international trade, the following patterns arise. Figure 2 plots imports to Germany at the product-level by the ten largest trading partners during 1980-2010. The most important trading partners for Germany are Netherlands, China, France, USA and Italy, with the strongest effects observed for China since the mid 1990s, indicating import competition in goods from China due to its reduced trade barriers and increased operation in the global market. Figure 3 plots the balance of trade for Germany since 1970s, which is simply given by the difference between net imports and exports. A strong trade surplus pattern is observed throughout the entire period of analysis, primarily due to Germany's strong presence in the export market in automobile, capital equipments and technology. The onset of the financial crisis in 2007 and the Euro crisis in 2009 is found to have a dampening effect on German exports, resulting in reduction in trade surplus during 2008-2011. However, trade surplus has continued to increase thereafter, contributing positively to GDP growth. Taken together, these indicate that Germany has experienced import penetration from EU (Netherlands, France and Italy) and non-EU countries (China and the U.S.), but to a significantly lesser extent as compared to findings from the U.S. (Autor et al. 2013).



Source: United Nations Comtrade Database

Figure 2: Germany imports by largest trading partners in billion US\$ (1980-2010)



Figure 3: Germany balance of trade in million Euro (1970-2014)

Clearly, the importance of global forces in explaining employment and wage movements in industrialized economies has been at the center of an intense debate in recent literature. However, depending on the regional, institutional and socio-economic characteristics of the particular local economy, the extent to which trade and technology overlap in shaping employment structure may vary significantly. U.S., for example, has experienced significant decline in unionization, minimum wage legislation and corporate governance since the early 1990s. Changes in the quality of education system, that is, slowing down of in the supply of skilled labor relative to rising educational returns has also contributed to wage inequality and employment polarization in the U.S. (Autor et al. 1998). In comparison, Germany has a well-established system of vocational education "apprenticeship" as well stronger labor market institutions "works councils" and wage setting regulations. Accordingly, one can expect significant cross-country differences due to regional and institutional characteristics on the pattern and magnitude of routinization in Germany, as compared to the U.S.

2.3 Regional Employment and Human Capital

Empirical studies dealing with falling employment in routine-intensive occupations and rapid growth of low-skilled non-routine manual occupations in industrialized economies focus mostly on aggregate trends (ALM 2003, Spitz-Oener 2006, Goos et al. 2009). However the literature on regional growth and innovation (Moretti 2004, 2010, Frenken et al. 2007, Mameli et al. 2012, Florida et al. 2011) provides evidence that employment outcomes differ signicantly across local labor markets in a country. These geographical differences are mostly attributed to varying rates of industrial specialization (Diamond and Simon 1990, Krugman 1991), institutional and wage settings (Card and Krueger 1995, Amin and Thrift 1995, Faini 1999), and human capital stock (Scott 2010, Abel and Deitz 2011, Winters 2013, Glaeser et al. 2014). Incorporating the regional aspect into the discussion on employment polarization, Autor and Dorn (2013) extend their general equilibrium model (ALM 2003) to a spatial framework where local labor markets have varying degrees of sectoral specialization in routine-intensive occupations. Using data on 722 commuting zones in the U.S. between 1980 and 2005, authors find significant regional differences in the adoption of ICT, displacement of routine labor and subsequent reallocation into non-routine service occupations, and wage growth. In the context of Germany, labor market regions vary extensively not only in administrative and political attributes but also in several socio-economic and institutional characteristics- such as, intensity of unionization, industrial specialization, presence of works councils and collective labor agreement, minimum wage requirements, provision for apprenticeship training and vocational education. Following closely Autor and Dorn (2013), we therefore focus on regional variation in West Germany particularly with respect to human capital and apprenticeship system in analyzing employment dynamics.

The apprenticeship system in Germany is based on the Vocational Training Act of 1969 that regulates the provision of training and vocational education on the part of private firms to young job-seekers in manufacturing, IT, financial and service sectors. Such training is usually aimed at career development of labor market entrants, and therefore determinant of their future labor market outcomes. Most often, apprenticeship takes the form of technical on-the-job training provided for up to three years by the companies undertaking such programs and in the end apprentices are either soaked up within the company or given a certificate as proof for successful completion of the program. Because apprenticeship training is expensive, firms providing 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 regional variation in the degree and intensity to which apprenticeship training is provided. In case of Germany, apprenticeship system is localized within the Federal employment agency districts "arbeits agenturbezirke" who report new apprentices hip contracts in response to apprenticeship vacancies reported by private firms. The quality of training provided to applicants is monitored by "competent bodies, mainly the chambers (of industry and commerce, crafts, agriculture, doctors, lawyers) but also by competent bodies in the public service or for the purview of the churches" (BIBB Vocational Education and Training VET report 2013, p. 9) and therefore guarantees national standard. In this sense, the institutional framework of the VET allows for close-cooperation between the federal agencies, industrial settings and local firms. The number of newly concluded training contracts increased significantly during the mid 1980s by approximately 7% in

relation to the start year of the survey (1979), and has hence decreased by roughly 23% in 2012. Furthermore, significant regional differences are observed in the supply and provision of traineeship contracts between East and West Germany, as well as among the employment agency districts therein (VET 2013). Figure 4 plots apprenticeship contracts by employment agency districts in 1979 and 2012, ranked by routine-employment share¹. Regions with highest routine-employment, on average, have undertaken greater apprenticeship contracts in 1979; while in 2012, least routine-intensive regions are found to be associated with highest apprenticeship contracts. Evidently, the figures point towards significant differences with respect to the importance of vocational training across regional employment districts in West Germany throughout the entire period of analysis.



Figure 4: Apprenticeship (1979 and 2012)

Building on this background we exploit regional variations in the displacement of routine jobs and growth of non-routine service jobs in the presence of a strong vocational education system. In case of Germany, apprentices are found to be most prominent in the traditional manufacturing sector which makes inter-industry reallocation somewhat sticky, when compared to the U.S. However, given that apprenticeship increases the skilllevel and human capital of workers, it is likely that provision of greater vocational training leads to skill-upgrading and reallocation of routine labor to high-skilled non-routine jobs. Therefore, we expect that employment districts undertaking higher investment in apprenticeship training will experience greater loss of middle-income and middle-skilled jobs and subsequent growth in the share of non-routine abstract occupations, than districts providing lower apprenticeship training. In this sense, the expectation is that greater apprenticeship training will accelerate the process of displacement of routine workers towards high-skilled occupations. The following section reflects these considerations and introduces the data and empirical strategy used to test the main research questions.

3 Data and Methodology

For the empirical analysis, the paper draws information from four main databases: the Qualification and Career Survey (QCS) data from BIBB/IAB (Bundesinstitut für Berufs-

¹see Figure 5 in Appendix for apprenticeship contracts for each time-period.

bildung and Institut für Arbeitsmarkt 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 OECD 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 ICT at workplace for more than 30,000 individuals each year in Germany. 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. However, given the reunification of Germany in 1990 and the significant political, social and economic changes that followed thereafter, we restrict our sample to only West Germany. Further, we concentrate on prime-aged workers between 17 and 64 affiliated in private sectors and exclude the public sector. 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, 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:

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

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 above expression of task measures implies that if, for example, the total number of activities in the non-routine analytic task category is four and individual *i* performs two out of them, the corresponding task-measure will be (2/4)*100=50.

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 (KldB92-2 digit). 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. Finally, the 80 occupational groups are grouped into 9 broad categories and the task- and technology measures are recalculated.

In order to assess the role of technology, international trade and human capital in shaping employment pattern in employment agency districts in Germany, the task-content and technology measures from BIBB/IAB are matched with the SIAB-R 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 KldB88-2 digit), occupationalstatus and industry affiliation. Additionally, the SIAB-R provides regional data on 326 NUTS-3 administrative districts ("landkreise" and "kreisfreie städte") in West Germany that indicates place of work of individuals. However, administrative districts are merely the result of political and constitutional arrangements, and have little economic validity. Therefore, for the purpose of our analysis, we use regional information on 138 employment agency districts "arbeits agenturbezirke" in West Germany that roughly correspond to commuting zones in U.S. based studies. Using this matched data, the regional taskmeasures are calculated in three steps. First, the occupational task-scores are further grouped into three categories: abstract (average of non-routine analytic and non-routine interactive), routine (average of routine manual and routine cognitive) and manual (nonroutine manual) for each occupational class. Second, the three task-measures are combined into a summary measure of routine task-intensity calculated as:

$$RTI_{k,t} = \frac{\left(Task_t^R\right)}{\left(Task_t^A\right) + \left(Task_t^M\right)}$$

where $Task_t^R$, $Task_t^A$ and $Task_t^M$ are respectively routine, analytic and manual taskcontent in each occupational class k in time t. The following summary table gives a brief overview of the task-content of major occupation groups in 1979.

$\begin{array}{c c c c c c c c c c c c c c c c c c c $	-	-	-	_	
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	Occupation	Abstract	Routine	Manual	Score
$\begin{array}{llllllllllllllllllllllllllllllllllll$	Agriculture	5.100	19.076	8.377	1
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Services	5.837	7.605	10.566	0
$\begin{array}{llllllllllllllllllllllllllllllllllll$	Construction and Trade	4.087	5.380	14.206	0
$\begin{array}{c ccccc} Clerical/Office related & 6.844 & 26.802 & 1.742 & 1 \\ Retail & 17.214 & 15.433 & 3.241 & 1 \\ Technicians & 16.848 & 12.415 & 9.420 & 0 \\ Professionals & 17.858 & 16.122 & 5.562 & 0 \\ \hline Managerial/Executive & 24.823 & 22.183 & 5.139 & 0 \\ \end{array}$	Production	4.266	10.069	4.663	1
Retail17.21415.4333.2411Technicians16.84812.4159.4200Professionals17.85816.1225.5620Managerial/Executive24.82322.1835.1390	Clerical/Office related	6.844	26.802	1.742	1
Technicians16.84812.4159.4200Professionals17.85816.1225.5620Managerial/Executive24.82322.1835.1390	Retail	17.214	15.433	3.241	1
Professionals 17.858 16.122 5.562 0 Managerial/Executive 24.823 22.183 5.139 0	Technicians	16.848	12.415	9.420	0
Managerial/Executive 24.823 22.183 5.139 0	Professionals	17.858	16.122	5.562	0
	Managerial/Executive	24.823	22.183	5.139	0

Table 1: Task-intensity measures by major occupation groups

Table 1 indicates the abstract, routine and manual task scores for each broad oc-

cupational category. To get a clearer picture, the final column explains whether the average RTI index in each occupational group is larger or smaller than the average RTI score across all occupational groups. Score= 1 indicates that an occupation is routine-intensive, while score= 0 indicates otherwise. Finally, the share of routine occupation in each employment agency district r in time t is calculated as:

$$Routineshare_{r,t} = \frac{\sum_{k=1}^{K} \mathcal{L}_{k,r,t} * RTI_{k,t}}{\sum_{k=1}^{K} \mathcal{L}_{k,r,t}}$$

where $L_{k,r,t}$ is the employment share in occupation k in employment district r in time t and $RTI_{k,t}$ is the routine task-intensity measure for each occupation k in year t. The above expression therefore indicates the share of routine-intensive employment in total employment in each employment agency district in a particular time period.

With regard to increasing globalization, the objective is to examine changes in the exposure to international trade for local employment agency districts in West Germany due to inflow of world imports. For this purpose, seasonally-adjusted sector level data on imports for West Germany is collected from the OECD database over the entire span of 1971-2012 and aggregated on the regional-level following the methodology proposed by Autor et al. (2013). Additionally, distinction is drawn between trade-exposure measures corresponding to imports in goods and services.

$$\Delta TradeExp_{r,t} = \sum_{j} \frac{L_{r,l,t}}{L_{l,t}} \frac{\Delta \text{TradeVal}_{l,t}}{L_{r,t}}$$

where $TradeExp_{r,t}$ is the exposure of each employment district r to import-competition in year t. $\frac{L_{r,l,t}}{L_{l,t}}$ is the share of region r's employment in sector l in time period t, out of national sectoral employment in l in time t. Δ TradeVal_{l,t} is the observed change in the absolute value (in millions, measured in U.S. dollars) of German imports from the rest of the world in industry l during each time interval t and $L_{r,t}$ is total employment in region r in each year. This measure captures the extent of globalization and offshoring in West Germany and is interpreted as the change in the share of aggregated sectoral imports of goods and services in each employment agency district during 1979-2012.

Finally, data on apprenticeship is collected from BIBB vocational education reports corresponding to the six waves of the QCS for all 138 employment districts in West Germany, and the extent of apprenticeship training is measured as the share of newly concluded training contracts at the end of each year over the employed population within each region. Incorporating all these information, we next present the most relevant results from our empirical analysis.

4 Main Findings

Following the outline provided in section 3, we first estimate two separate regressions on the variations in the degree of routinization and computer adoption across employment agency districts in West Germany. Regional variation in technology adoption and displacement of routine-intensive employment is attributed to the initial conditions of a particular region being routine-intensive. Accordingly, we estimate two separate regression models: a) effect of routine-employment share in each employment agency district in West Germany at the start of each period on the percentage change in computer adoption for the overall period 1979-2012, and b) effect of routine-employment share in each labor market district in West Germany at the start of the period on the percentage change in share of regional routine occupation during the entire period. In other words, we estimate to what extent initial share of routine-employment in an employment district explains subsequent change in the share of routine-employment and adoption of computer technology in the region over time. The following two empirical specifications reflect these considerations:

$$\Delta PC_{r,t} = \beta_0 + \beta_1 \text{Routineshare}_{r,t-1} + \beta_2 X'_{r,t} + \epsilon_{r,t} \tag{1}$$

$$\Delta Routineshare_{r,t} = \beta_0 + \beta_1 \text{Routineshare}_{r,t-1} + \beta_2 \mathbf{X}'_{r,t} + \epsilon_{r,t}$$
(2)

The dependent variable in equation 1 indicates the difference in the regional share of PC adoption between each subsequent wave of the QCS (1979-1986, 1986-1992, 1992-1999, 1999-2006 and 2006-2012) while the independent variable is the regional share of routine employment at the start of each subsequent wave, over 138 employment agency districts for West Germany. Similarly, dependent variable in equation 2 indicates the difference in the regional employment share in routine-intensive occupations between each subsequent wave that is explained by initial routine-employment in each region. X' denotes the vector of all additional variables and controls. Pooling all years, the final sample consists of 828 observations (138*6) and simple OLS estimation is run for each specification. Additionally, standard errors are clustered on the level of regional directorate districts (Regionaldirektionsbezirke) and year and district-level dummies are included in the model; however not reported for the sake of brevity.

I						
	Δshe	are of pcado	ption	$\Delta share$	re of routine	e empl
		Pooled OLS			Pooled OLS	
Routine sharet-1		13.710***			-0.755***	
		(1.231)			(0.017)	
Constant		-0.362**			0.081***	
		(0.144)			(0.002)	
Year dummies		Yes			Yes	
State dummies		Yes			Yes	
R-squared		0.98			0.98	
	1979-1992	1992-2006	1979-2012	1979-1992	1992-2006	1979-2012
Routine sharet-1	15.768***	-10.869*	7.923***	-0.873***	-0.942***	-1.156***
	(2.277)	(4.925)	(1.445)	(0.016)	(0.051)	(0.022)
Constant	1.019**	6.468***	7.434***	0.105***	0.055***	0.081***
	(0.273)	(0.593)	(0.173)	(0.003)	(0.006)	(0.003)
R-squared	0.66	0.15	0.36	0.91	0.67	0.98

 Table 2: Change in computer adoption and routine-employment in agency districts 1979-2012

*p<0.10 **p<0.05 ***p<0.01

Top panel: Number of observations =690 (138*5). Bottom panel: Number of observations = 138 Standard errors in parenthesis are clustered on district state-level

State dummies are included. Year dummies included for stacked regression (Top panel: Base year 1986).

The top panel of Table 2 presents stacked first differences in the share of computer adoption and routine employment for the entire period, while the bottom panel estimates separately the routinization hypothesis for each subgroup, before reunification (1979-1992), after reunification (1992-2006) and for the entire period (1979-2012). First, regions with a high initial share of routine occupation is found to have experienced greater subsequent adoption of computer and information technology between 1979 and 2012. Additionally, these regions experienced larger subsequent decline in routine occupations since 1979. These two findings confirm Autor et al. (2013) results for the U.S. labor markets in case of West Germany, that relative demand for routine-intensive jobs has indeed gone down since the 1980s in the wake of rising ICT usage in local employment districts. Looking next at the bottom panel, significant differences in routinization are observed across subgroups. Employment agency districts initially specialized in routine-intensive occupations experienced greater adoption of technology during 1979-1992, after which it substantially slowed down. With respect to regional variation in the share of routine-intensive occupations, employment has fallen throughout 1979-2006. Taken together, these findings indicate that the effect of technological progress on employment structure was most evident during the 1980s and 1990s in West Germany and significantly decelerated during mid 1990s and 2000s.

So far, regional routine task-content of occupations and differential adoption of ICT at workplace have explained falling relative demand and employment share of routineintensive occupations across employment districts in West Germany. While computerization is certainly the most dominant contributor to routinization and regional employment dynamics, it is essential to investigate the extent to which such changes are influenced by exposure to international trade, underlying vocational education structure and demographic and sectoral characteristics of each local region during the overall period. For that purpose equation 2 is re-estimated, additionally taking into account the contemporaneous change in import exposure with respect to goods and services per employee and initial share of apprenticeship contracts adopted at the start of each period in each employment agency district. Furthermore, several region-specific control variables are included relating to the initial share of women in total employment, initial share of college-educated workers in total employment, initial share of workers with vocational education in total employment and initial share of workers affiliated with the manufacturing sector in total employment. Regional employment consists of both full-time and part-time employment, male and female, and only prime-aged workers. Table 3 presents results from the step-by-step augmented pooled OLS model:

Model 1 and Model 2 of Table 3 build upon the base model presented in Table 2 by additionally considering exposure of each local employment district to international trade (world imports) in goods and services. As expected and in line with the substitutability property of ICT, regions with high initial share of routine employment experienced greater reduction in routine-employment in each subsequent time period between 1979-2012. With respect to trade in goods, the point estimate of 0.003 is statistically significant and positive, implying that regions with high exposure to world imports experience subsequent increase in routine-employment share. However, when we consider trade in services, the point estimate of -0.065 is statistically significant and substantially large in magnitude implying that increase in trade exposure with respect to services reduces overall employment in routine-intensive occupations². Model 3 confirms negative employment effects for both trade and technology, however with significantly larger magnitude for routinization and computerization vis-à-vis import competition. Model 4 incorporates the human capital aspect of regions, by including the initial share of apprenticeship contracts at the start of each period and subsequently investigating its effect

²One reason for this observation could be multicollinearity, following which we have provided alternate specifications in the Appendix where all variables of interest are included separately in subsequent models

Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
-0.782***	· -0.787***	· -0.784***	-0.746***	-0.774***	-0.787***
(0.013)	(0.015)	(0.016)	(0.016)	(0.015)	(0.024)
0.003^{***}		-0.004***		-0.003***	-0.002**
(0.001)		(0.001)		(0.001)	(0.001)
	-0.065***	· -0.135***		-0.126***	-0.044
	(0.010)	(0.016)		(0.016)	(0.023)
			-0.001***	-0.001***	-0.001*
			(0.001)	(0.001)	(0.001)
					-0.007
					(0.004)
					-0.034***
					(0.002)
					0.009
					(0.006)
					0.009^{***}
					(0.002)
0.084^{**}	0.087^{***}	0.088^{***}	0.088^{***}	0.094^{***}	0.089^{***}
(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Yes	Yes	Yes	Yes	Yes	Yes
Yes	Yes	Yes	Yes	Yes	Yes
0.99	0.99	0.99	0.99	0.99	0.99
	Model 1 -0.782*** (0.013) 0.003*** (0.001) 0.084** (0.002) Yes Yes 0.99	Model 1 Model 2 -0.782*** -0.787*** (0.013) (0.015) 0.003*** -0.065*** (0.010) -0.065*** (0.010) -0.065*** (0.010) -0.065*** (0.010) -0.065*** (0.010) -0.065*** (0.010) -0.065*** (0.010) -0.065*** (0.002) (0.002) Yes Yes Yes Yes 0.99 0.99	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c c c c c c c c c c c c c c c c c c c $

Table 3: Change in routine-employment in employment agency districts 1979-2012: Role of Technology, Trade and Apprenticeship

Number of observations =690 (138*5), *p<0.10 **p<0.05 ***p<0.01

Standard errors in parenthesis are clustered on district state-level

State dummies are included. Year dummies included for stacked regression (Base year 1986).

on the dynamics of regional employment structure. The corresponding point estimate is negative and small in magnitude, while highly significant, implying that regions that undertook greater apprenticeship contracts experienced greater subsequent displacement of routine-intensive occupations. Results stay robust in Model 5 when both technology, trade and apprenticeship are included, with technology being the foremost contributor to declining regional routine-employment share. Finally, Model 6 includes additional controls allowing for heterogeneity across employment districts in terms of demographic and sectoral characteristics. Firstly, trade exposure in services and intensity of apprenticeship training lose significance when considering the full model, while no significant differences are observed with respect to technology and trade exposure in goods. The coefficient for share of high-skilled college educated employees in the total workforce turns out to be significant, high and negative, implying that greater share of workers with college/university degree in regions predicts greater decline in routine-occupations. No significant effect on employment pattern is found for female and vocational employment, while regions with a higher initial share of manufacturing employment is found to have experienced a greater decline in routine-intensive occupations, as is expected.

While evidence until now establishes the predictive capability of occupational taskcontent, technology, trade and human capital in explaining decline in routine employment in labor districts in West Germany, the question that arises next is where do displaced routine-workers move? According to Autor et al. 2013, polarization arises due to reduced demand for routine-intensive occupations coupled with rapid increase in the share of low-skilled service occupations in the U.S. labor markets since the 1980s. However, they do not specifically look at changes in employment pattern for high-skilled abstract occupations, predicted by the traditional and non-traditional forces. Accordingly, the final section of the study addresses this gap and estimates the relationship between initial routine employment shares in each local labour market on the percentage change in the share of low-skilled non-college service occupations and high-skilled abstract occupations throughout the entire period 1979-2012. Typically, we run the following model:

$$\Delta Low \ skilled \ service_{r,t} = \beta_0 + \beta_1 \text{Routineshare}_{r,t-1} + \beta_2 X'_{r,t} + \epsilon_{r,t}$$
(3)

$$\Delta Share \ of \ abstract \ occup_{r,t} = \beta_0 + \beta_1 \text{Routineshare}_{r,t-1} + \beta_2 X'_{r,t} + \epsilon_{r,t}$$
(4)

As before, we run simple OLS regression on the pooled sample for the entire period where the main independent variables of interest are the share of routine occupations at the start of each period, change in trade exposure with respect to goods and services and intensity of apprenticeship corresponding to each employment agency district; while the dependent variables are a) first-differenced measure of non-college low-skilled service occupations over each subsequent period and b) first-differenced measure of highskilled abstract/cognitive occupations over each subsequent period. By construction, low skilled service occupations include employment in consumer goods industry, hospitality industry and public, private and household services and high-skilled non-routine occupations include technicians, engineers, scientists and other technical professionals, other professionals and managerial/executive personnel (see Table 1 for overview on routine/abstract/manual task-measures). Further we include all demand-side factors that can have an effect on the growth of non-routine occupations, year dummies and employment district-level dummies for West Germany and adjust the standard errors accordingly. Table 4 presents the results from the estimation.

The overlap between initial regional routine employment and subsequent growth of low-skilled service occupations is surprisingly weak for the first two models in Table 4. However when considering the full model (Model 3), the positive significant coefficient indicates that regions with a greater share of routine jobs experienced greater growth of low-skilled service jobs in the subsequent periods. However, regions' exposure to international trade in goods is found to reduce overall low-skilled service employment, reaffirming Autor and Dorn's (2013) findings for the U.S., whilst that in services provides mixed results. With respect to apprenticeship, initial share of apprenticeship contracts provided in regions is found to have significant effect on the percentage change in the share of low-skilled service occupations for the entire period, while it loses significance when considering the full model. When considering growth in the share of high-skilled non-routine occupations, initial routine employment share is found to strongly predict changes in employment pattern in all three model specifications implying that regions initially specialized in routine-intensive jobs experienced greater subsequent increase in non-routine high-skilled occupations. This finding is highly intriguing for us for two reasons: First, it points towards skill-upgrading and movement of displaced routine-workers up the occupational ladder. Second, so far no studies for Germany have confirmed routine task-content of occupations as a significant predictor of growth in abstract occupations. However, no effect of trade exposure or apprenticeship is observed. These results could indicate that employment effects of increased import competition and apprenticeship is mostly limited to changes in employment in routine occupations and to some extent in non-routine service occupations, but do not necessarily predict growth in non-routine high-skilled oc-

	Δίου	v – skille	d share	Ahiah	– skilled	share
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Routine sharet-1	0.257	0.187	0.315**	0.204***	0.209***	0.206***
	(0.157)	(0.160)	(0.148)	(0.016)	(0.167)	(0.019)
D.exposure to imports (goods)		-0.016*	-0.024**		-0.002	-0.001
		(0.009)	(0.010)		(0.001)	(0.001)
D.exposure to imports (services)		-0.409**	0.775***		-0.023	-0.004
, , ,		(0.183)	(0.219)		(0.022)	(0.022)
Apprenticeshipt-1		0.003**	0.001		0.001	0.001
		(0.001)	(0.001)		(0.001)	(0.001)
Share of female emplt-1		× /	-0.114***		· /	-0.007***
			(0.029)			(0.003)
Share of college-educated emplt-1			0.033			-0.004
			(0.034)			(0.004)
Share of vocational emplt-1			-0.006			-0.008
			(0.067)			(0.007)
Share of manufacturing emplt-1			-0.077 ***			-0.001
			(0.015)			(0.002)
Constant	-0.037*	-0.042**	0.036*	-0.008***	-0.009***	-0.005*
	(0.0187)	(0.021)	(0.022)	(0.002)	(0.002)	(0.003)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
State dummies	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R-squared	0.11	0.12	0.20	0.95	0.95	0.95

Table 4: Non-college low-skilled service occupation and high-skilled abstract occupation in local employment districts 1979-2012

Number of observations =690 (138*5), *p<0.10 **p<0.05 ***p<0.01

Bootstrapped standard errors in parenthesis, reps 200

State dummies are included. Year dummies included for stacked regression (Base year 1986).

cupations. With regard to the control variables, regions with low female workforce share are found to experience greater growth in low-skilled service occupations as well as highskilled occupations. This is surprising, given that female workforce are more likely to be associated with household services and hospitality industry. No significance is found with respect to share of vocationally- and college educated employees in regional workforce, whereas regions with a lower initial share of manufacturing employment experienced a higher growth of low-skilled service occupations.

5 Conclusion

The goal of the present study was to verify the recent evidence on the dynamic patterns of employment polarization in Anglo-Saxon countries using a continental European model. Germany has since long attracted attention from scholars on account of its strong institutional settings, minimum wage regulations, technological advancement and political peculiarity. The country experienced severe unemployment during the 1980s, which catapulted into the establishment of strong labor market institutions, employment protection laws and improved education systems. With respect to the political climate, year 1990 marked the period of German reunification, which in turn, served as a propellant for the economic restructuring of Europe. Moreover, during this time, Germany emerged as one of the main producers of latest technologies in automobile, information and communication, nanotechnology and renewable energy. Given this background and analytical framework, the question of whether Germany experienced the familiar U-shaped employment profile observed in the U.S. in the last three decades, of increased employment in high skilled along with low skilled service occupations, remains a matter of continuing interest. The study advances in this direction by examining changes in occupational skill-complexity due to adoption of ICT and increased scope of international trade, within a rich vocational backdrop in West Germany during 1979-2012. In so doing, emphasis is placed on employment agency districts in order to exploit regional variations in the extent to which trade and technology overlap in shaping employment pattern. Moreover, provision of apprenticeship training and vocational education is taken into account to understand if such changes are amplified or hampered by local/regional institutional settings.

Employing simple OLS estimations on the pooled sample at the level of employment districts, findings suggest that block of occupations at the center of the skill distribution, typically routine-intensive in content, have decreased since 1979. Employment districts with high initial share of routine occupations at the start of each period experienced greater adoption of computer and information technology along with larger decline in routine occupations over subsequent periods. Concerning the effect of globalization on regional employment, greater exposure to international trade in the form of imports in goods and services further reduced employment in routine-intensive occupations. These findings are in line with recent U.S. based studies, but differ strongly when institutional differences across regions are considered. Regions that undertook greater apprenticeship contracts experienced greater subsequent displacement of routine-intensive occupations, indicating movement of displaced routine-workers along the occupational ladder. However, unlike in the U.S., regions with greater share of routine jobs experienced greater growth of high-skilled abstract jobs in the subsequent periods, while providing weak evidence on the overlap between initial regional routine employment and subsequent growth of low-skilled service occupations. Put differently, while there has been somewhat growth in service sector employment in West Germany in recent decades, it has not occurred to the same degree as compared to the U.S. Instead, a greater trend towards occupational upgrading and larger growth in managerial and professional occupations is observed, pointing towards significant institutional differences in employment trends between the U.S. and Germany. These findings add to the few recent empirical works on Germany in three ways: First, by undertaking a longer time frame that allows us to examine not only historical changes in employment pattern but also recent trends. Second, by bringing international trade into the picture as an important contributor to routinization. Finally, by considering the hitherto unexplained role of institutions, specifically, vocational education system in explaining the differential pattern of employment growth in West Germany as juxtaposed with evidence from the U.S. labor markets.

While the study offers new insights into the discussion on regional variation in polarization pattern, it is not free from limitations. First, the measure for technology used in the study, although providing sufficient comparability with existing literature, limits the possibility of examining recent technological advancements. For that purpose, one should take into account advanced measures such as patents, publications and new capital equipments to determine the extent to which regions are technologically progressive. Second, limited information on regional characteristics do not allow us to incorporate aspects of regional specialization, industry diversification, inter-region migration and historical unemployment. A thorough analysis incorporating these additional information is, therefore, essential for further research. Third, the chapter analyzes the relationship between initial routine-intensity of regions and subsequent changes in routine-based manufacturing/clerical occupations and low-skilled service employment. However, this does not take into account unobserved factors that causes routine-employment to vary across regions, and calls for an instrumental variable estimation using data prior to the start of the period of analysis (Autor and Dorn 2013). Finally, regional exposure to international trade is calculated using sector-level import data in the current study. While this method ensures simpler implementation, it does not consider employment changes within and between industries. Consequently, the next step is to use information from Input-Output tables for (West) Germany to construct measures of trade-intensity at the level of industry and subsequently formulate regional measures.

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Appendix





Figure 5: Apprenticeship (1979-2012)

		D.:	Ule J: ESU	IIIauon re	INI W SULLS		e specifica	SIIOI		Abc	+004	
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	ADS Model 2	Model 3	Model 4
Routine share	-0.794^{***} (0.021)				0.371^{**} (0.151)				0.198^{***} (0.017)			
D.exposure imports (goods)	~	-0.004^{**} (0.002)			~	0.010^{**} (0.004)			~	-0.001 (0.001)		
D.exposure imports (serv)		~	0.072^{*} (0.034)			~	-0.307^{***} (0.085)			~	0.002 (0.012)	
Apprenticeshipt-1				-0.001***			~	0.001			~	0.001
Share of female emplt-1	-0.015	-0.015	0.026	-0.011	-0.142^{***}	-0.126^{***}	-0.116^{***}	-0.140^{***}	-0.006**	-0.006*	-0.006*	-0.005*
Show of collows analy 1	(0.003)	(0.009)	(0.010)	(0.009)	(0.029)	(0.031)	(0.030)	(0.030)	(0.002)	(0.003)	(0.003)	(0.003)
r-udura agained to arrite	(0.001)	(0.005)	(0.005)	(900.0)	(0.033)	(0.033)	(0.033)	(0.033)	-0.004 (0.004)	(0.004)	(0.008)	(0.004)
Share of vocational emplt-1	0.008	0.120^{***}	0.117^{***}	0.113^{***}	-0.023	-0.079	-0.071***	-0.071	-0.010	-0.037***	-0.037***	-0.036***
Show of moniform]t 1	(0.005)	(0.013)	(0.013)	(0.012)	(0.067)	(0.064)	(0.064)	(0.065)	(1000)	(0.008)	(0.008)	(0.008)
DIRATE OF THATTAL CULTURE	(0.001)	(0.005)	(0.005)	(0.003)	(0.012)	(0.014)	(0.014)	(0.012)	(0.001)	(0.002)	(0.002)	(0.001)
Constant	0.087^{***}	-0.012***	-0.014^{***}	-0.005	0.021	0.066^{***}	0.072^{**}	0.063^{***}	-0.004	0.021^{***}	0.021^{***}	0.019^{***}
	(0.002)	(0.004)	(0.004)	(0.004)	(0.022)	(0.014)	(0.015)	(0.016)	(0.003)	(0.001)	(0.001)	(0.002)
Year dummies	Yes	\mathbf{Yes}	Yes	Yes	Yes	\mathbf{Yes}	Yes	Yes	\mathbf{Yes}	\mathbf{Yes}	\mathbf{Yes}	$\mathbf{Y}_{\mathbf{es}}$
State dumnies	\mathbf{Yes}	\mathbf{Yes}	Yes	\mathbf{Yes}	Yes	\mathbf{Yes}	\mathbf{Yes}	Yes	\mathbf{Yes}	\mathbf{Yes}	Yes	Yes
R2	0.98	0.98	0.98	0.98	0.19	0.19	0.20	0.18	0.95	0.94	0.94	0.94
Number of observations $=690$	$(138^{*5}), *_{\rm F}$	<0.10 **p<	<0.05 ***p<	0.01								
Bootstrapped standard errors	in parenthe	esis, reps 20	0									
State dummies are included.	Year dumm	ies included	for stacked	regression	(Base year	1986)						

Change in computer adoption	1										
Routine share	-0.069	1									
Change in Routine share	-0.197*	-0.564^{*}	1								
Change in Abstract share	0.290^{*}	0.204^{*}	-0.550*	1							
Change in Low-skilled service share	-0.196*	-0.010	-0.116^{*}	0.001	1						
Female empl share	0.029	-0.629*	0.114^{*}	-0.121^{*}	-0.046	1					
College educated share	-0.091^{*}	-0.446*	0.033	-0.116^{*}	0.223^{*}	0.375^{*}	1				
Vocational share	0.057	0.372^{*}	0.030	-0.336*	-0.083*	-0.281	-0.487*	1			
Manufacturing empl share	0.003	0.419^{*}	-0.080*	0.104^{*}	-0.231*	-0.440	-0.500*	-0.010	1		
Change in Import exposure (goods)	0.249^{*}	-0.759*	0.508^{*}	-0.333*	-0.043	0.385^{*}	0.220^{*}	-0.239*	-0.027	1	
Change in Import exposure (services)	0.330^{*}	-0.772*	0.447^{*}	-0.529*	-0.050*	0.577	0.387^{*}	-0.048	-0.456	0.690^{*}	1
Apprenticeship	-0.141*	0.287^{*}	-0.012	-0.066	0.074	-0.305*	0.155	-0.024	0.034	-0.246*	-0.210* 1

Table 6: Correlation Table

Correlation matrix: Correlations greater than or equal to 0.08 (in absolute terms) are significant (p< 0.05)