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## Occupations at risk: The task content and job security

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by

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# Occupations at risk: The task content and job security\*

Ljubica Nedelkoska<sup>†</sup>

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## Abstract

We study the occupational dynamics in the Western part of Germany over the last three decades and confirm that occupations characterized by high intensity of interactive and problem-solving tasks increased their employment share at the expense of occupations with a high level of codifiable tasks (tasks that can be described by step-by-step procedures or rules). We provide evidence at the individual level that jobs which involve a high instance of codifiable tasks are associated with lower job security. The pattern is present at different educational levels and in various broadly defined industries. The results are in line with a theory of technological change where code-based technologies substitute for codifiable tasks.

JEL classification: J21, J24, J63

Keywords: skills, tasks, occupations, job security

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## 1 Introduction

It is common knowledge that developed economies have vastly restructured from manufacturing to service dominated sectors - a process that is still in progress. We also know the meaning of this transition in terms of production of goods and services. Economies are furthermore familiar with its consequences on employment restructuring. What has not been elaborated extensively enough are the implications of such structural change on the occupational and the skill structure of economies. A question even less researched is the extent to which the task and skill composition before the major structural change made the economy prone to changes. The purpose of this study is to contribute to an understanding of the changes in the West German occupational and skill structure in the last few decades.

It has been argued that work tasks that can be expressed in step-by-step procedures or rules (routine tasks) are more vulnerable to the influence of technology and international outsourcing. It has been further argued that routine tasks are mostly concentrated in jobs that are found in the middle of the wage distribution. At the same time, the middle-paid jobs have been those to decline most in several developed countries in the last decades (Goos and Manning 2007; Dustmann, Ludsteck, and Schönberg 2009; Goos, Manning, and Salomons 2009). Goos and Manning (2007) refer to the improvement of the labor market position of the occupations at the bottom and top of the wage distribution relative to the middle as labor or job polarization. They connect job polarization with the more nuanced theory of skill-biased technological change proposed by Autor, Levy, and Murnane (2003) which they refer to as routinization hypothesis. They propose that the routinization of labor (substitution of labor that performs repetitive and explicit tasks with technology) can explain the increase in the employment share both at the top and the bottom of the wage (skill) distribution relative to the middle.

We contribute to the literature by elaborating the relationships between wages and occupational employment growth, wages and task distributions, and tasks and job security in West(ern) Germany for the periods before and after the German reunification. We ask the following questions: (a) What do occupations that increased their employment share in the observed years have in common in terms of task and skill profile? (b) What do occupations that decreased their employment share in the observed period of time have in common in terms of task and skill profile? (c) Is the relationship between work-task content and employment growth of occupations (job security of employees) in accordance with the proposed nuanced theory of skill-biased technological change (Autor, Levy, Murnane 2003)?

We find that the monotone positive relationship between wages and employment share growth of occupations deteriorated in the years between 1975-2004 and that a U-shaped relationship between wages and employment growth gives a better fit. However, this pattern of job polarization is not as pronounced as in the case of the U.S. and the U.K. The reason is that many high-growth service-intense occupations were already well paid in the 1970s. We further find that the instance of frequent use of explicit or codifiable task content correlates highly with the perceived layoff risk at the individual level. The correlation is present at various educational levels and within different broadly defined industries. This is also evident both before and after the German reunification. These results are in line with the nuanced theory of skill-biased technological change proposed by Autor, Levy, and Murnane (2003).

The rest of this paper is structured as follows. Section 2 discusses the theory and the consequences of knowledge codification and derives the hypotheses. Section 3 introduces the data, section 4 describes the job polarization in Germany, section 5 addresses the between and within

changes in the intensities of different tasks. Section 6 makes the connection between task content of jobs and job security. Section 7 concludes.

## 2 The codification of knowledge and its implications for job security

An important dimension of knowledge is its tacitness, as Michael Polanyi elaborated in his 1967 work. One part of our knowledge can be articulated, verbally explained or written down to an extent that another person to whom it is communicated can comprehend its essence and be able to follow clear instructions. Another part remains less accessible to others either due to our inability to explain what we know or due to the fact that what we do, e.g., the way we reach solutions for a set of problems, is not well known to us either. By making what we know understandable for, and *reproducible* by, others, we turn tacit knowledge into explicit or codifiable knowledge.

Cowan and Foray (1997) define knowledge codification as “the process of conversion of knowledge into messages which can be then processed as information” (p. 596). The authors point out the dynamic character of knowledge that becomes more codifiable as it ages. Knowledge creation typically starts as being entirely tacit, as an idea. The process turning idea development into useful knowledge can also be highly tacit. As knowledge becomes better understood, and as it becomes feasible to disentangle it into explicit rules and steps, the process of codification starts. In some cases, “a procedure becomes routinized and repeatable, which implies that it can be broken down into component pieces, each of which is sufficiently simple that it can be described verbally or embodied in a machine.” (p.595).

The articulation of tacit knowledge is relevant for several reasons. The most important of these is probably that it enables knowledge transmission

through learning from others. In most instances this is beneficial because it allows for a large upgrading of human capital through education and training. Two other consequences of knowledge codification, however, have more ambiguous consequences. First, once codified, knowledge becomes easily transferable from one person to another, increasing the substitution elasticity among labor. Hence, the monopoly power over own skills is reduced and so is the price of labor.<sup>1</sup> This reasoning is in line with the recent evidence that domestic labor in developed countries has been substituted through cheaper labor in developing countries in such a way that less-skilled labor has been more affected than labor with more complex skills. In his theory of offshorability of jobs in the U.S. economy Blinder (2006) argues that the degree to which a job will be outsourceable in future depends on the degree to which it involves direct interaction with customers. Another important dimension of jobs, Blinder agrees, is the level to which their work content can be broken down into simple, routinizable tasks (p. 43). With everything else remaining constant, jobs that involve routinizable tasks are more outsourceable than jobs involving complex thinking, judgment and nonroutine human interaction. Therefore, despite the low skill requirements for jobs such as waiting staff or hairdressers, these jobs are at low risk of outsourcing.

Second, codifiable knowledge can be easily written in a machine code, rendering skills of human labor potentially substitutable by technologies. It has been widely claimed that information technologies (IT), being powerful systems of knowledge codification, have drastically shifted the skill composition of developed countries toward higher use of nonroutine work

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<sup>1</sup>The same type of reasoning can be applied to product inventions. This has been well known among industries whose products are made apparent by looking at a bare recipe. For example, Cohen, Nelson and Walsh (2000) show that, among several available ways of protecting innovation from imitation which include patents, licensing, lead time etc., secrecy is still considered the most effective way of product innovation appropriability by almost all 34 interviewed industries.

tasks. Autor, Levy, and Murnane (2003), when explaining which types of tasks can be substituted by computers, write:

“...[computers] rapidly and accurately perform repetitive tasks that are deterministically specified by stored instructions (programs) that designate unambiguously what actions the machine will perform at each contingency to achieve the desired result...A task is “routine” if it can be accomplished by machines following explicit programmed rules...Because these tasks require methodical repetition of an unwavering procedure, they can be exhaustively specified with programmed instructions and performed by machines” (p. 1282/1283).

We prefer to refer to technologically substitutable tasks as codifiable and not as routine because the latter term, although precisely defined in the work of Autor, Levy, and Murnane, causes some confusion about what is in fact programmable and what is prone to technological substitution. A task does not have to be routine in order to be codifiable. Reaching analytical solution of a complex mathematical model, or presenting relationships between data in the form of a statistical model are not necessarily routine tasks, but they are explicit. Moreover, a task does not have to be repetitive in order to create economic incentives for technological substitution. It is true that programmable tasks that are highly repetitive (e.g., bricklaying, product labeling, or sorting) create incentives for technological diffusion because such repetitive processes are labor intensive. However, complex but explicit tasks also create such incentives because they are labor intensive due to the task complexity itself. Moreover, labor capable of performing tasks will necessarily be scarcer and therefore better priced than labor that performs simple repetitive tasks. It has been widely discussed that technologies are often developed with the purpose of substituting scarce, and therefore expensive labor (Habakkuk. 1962, Acemoglu 2003).



This further brings us to the point that not all tasks that are codifiable are actually being substituted by technology. The first and obvious reason for this is that there are moving limits to automation science: for instance, the patent for the first mechanical tabulation machine was launched in 1889 (e.g., Kistermann 1991), most of the ATM and ATM-like patents were issued in the 1960s (Batiz-Lazo and Reid 2008), and most of the construction automation is still in its infancy even today (Balaguer and Abderrahim 2008). The second and perhaps more important reason is that there is a discrepancy between the point of invention and the diffusion period of a labor-substitutable technology. In some cases the initial price of the technology does not justify its implementation, in other safety issues are difficult to resolve. At the dawn of the industrial revolution in Great Britain labor-saving innovations such as the Spinning Jenny had to be hidden from the masses of agonized wavers whose labor price they sunk. Today there are robots that can replace the janitor's work or the work that involves care for others which have not diffused yet (and may not diffuse in the near future either); the semi- or completely robotized train is a 1960s invention, but its first and slow implementation started just few years ago in Germany, with 10 fully functional robotized subways currently operating in Nuremberg (Siemens AG. 2008).

Up to this point, we have elaborated on the kind of labor codifiable by technologies and stated that such labor, if it does not involve intense interaction with customers, may be more internationally outsourceable than labor that does involve such interaction. Therefore, here we can now state the hypotheses we would like to test with respect to the job security of employees whose work incorporates tasks with codifiable content. Without disentangling the sources of labor substitution, we expect that:

H1: Employees who report a high instance of codifiable tasks report higher risk of layoff

H2: The layoff risk of employees with a high instance of codifiable tasks decreases to the extent that their work also incorporates interactive tasks

It is further argued that labor prone to technological substitution and international outsourcing can be found at any educational level. Blinder, for example, proposes that the probability to be offshored is independent of the educational level required for the job. Autor, Levy, and Murnane (2003) find that shifts away from codifiable tasks are prevalent at all education levels.

H3: The relationships between the frequency of codifiable tasks and the layoff risk hold at different levels of education.

### **3 Data**

We use two datasets for this analysis. One is the Qualification and Career Survey and the second is the IAB Employment Samples (IABS). The first dataset is our source of information about individual, work-related tasks and skills as well as the individual level layoff risk. We mainly rely on the second dataset for employment and wages information. The information from the first dataset is merged with the IABS at the occupational level.

### 3.1 Qualification and Career Survey

The Qualification and Career Survey is a repeated cross section conducted at 6- to 7-years intervals, which started for the first time in 1979<sup>2</sup>. Its purpose, among others, is to track skill and task requirements of occupations. The survey is a rich source of information about the types of tasks employees perform in their jobs. Unfortunately, it repeatedly changed its structure, and many relevant questions are not consistently asked in each wave. We use all five waves of this survey, 1979, 1985, 1991/1992, 1998/1999, and 2005/2006, in order to compare the within and between-occupational changes in the use of tasks that are identically defined across waves. Here we use questions that are strictly comparable in at least four waves (see table 9 in the appendix A). Since for certain analyses it is useful to reduce the dimensionality of the data, we use the 1979 wave to conduct factor analysis (as explained in appendix B). After careful inspection of the questions in each wave we concentrate on those that are relevant for our purpose and identical or closely comparable between waves (see table 9 in the appendix A).

### 3.2 The measurement of task codification and task intensities

Two measures are of central interest in this paper: repetitiveness and explicitness of work tasks. Two questions in the Qualification and Career Survey that, we believe properly capture the degree of task codification appear in all five waves in a consistent manner. The first question reads:

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<sup>2</sup>The Qualification and Career Survey is administrated by the Federal Institute for Vocational Education and Training (BIBB) and the Institute for Employment Research (IAB).

How often does it happen that the same work step *repeats itself in each and every detail* of your daily work? This is our indicator of the repetitiveness of tasks. The second question reads: How often does it happen that you are being *instructed about the work process in each and every detail* of your daily work? The answer is given on a Likert scale: practically always, often, from time to time, seldom, practically never<sup>3</sup>. The use of these questions as measures of task codification has a number of advantages when compared to the choice of questions that Spitz-Oener (2006) and similar studies use to indicate routine tasks.<sup>4</sup> First, the classification is less arbitrary. For instance, one may rightfully agree that researching and analyzing are mainly analytical tasks, while advising customers, entertaining or presenting are mainly interactive tasks. However, categorizing calculating, bookkeeping and correcting of text and data as routine tasks is more ambiguous, as all these activities, although admittedly more routine, involve intellectual judgment. Second, close inspection of the variables in the Qualification and Career Survey that have been used to measure routine work before reveals large inconsistencies in their formulation. Any analysis of the within changes in the task content will be sensitive to the change in the question design. Third, when more arbitrary choice of variables is used, many notably routine tasks, such as sorting, pressing, labeling, stocking, and related assembly-line activities remain out of the focus of the analysis due to the fact that they have been asked only in one of the survey waves. Table 1 presents the tasks with which at least one of our measures of task codification is positively and significantly correlated.

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<sup>3</sup>In the 2005/2006 survey, the option “practically always” is absent.

<sup>4</sup>Spitz-Oener (2006) indicates the following tasks as routine cognitive: calculating, correcting text/data, bookkeeping, measuring length/weight/temperature. She classifies operating or controlling and equipping machines into routine manual tasks.

Table 1: Correlations between task codification and other tasks

	Explicitness	Repetitiveness
Work under norm	.78*	.62*
Machine knowledge	.29*	.02
Melt, cast, spreng	.23*	.13
Shape, form	.24*	.16
Building of canals, street paving	.27*	.11
Sawing, quilting	.47*	.26*
Packing, shipping preparation	.37*	.48*
Product stocking	.30*	.27*
Sorting, labeling	.11	.34*
Transporting	.51*	.36*
Observations	116	

Source: Qualification and Career Survey, 1979 wave

We see that at the occupational level, the explicitness and repetitiveness of tasks relate to many of the tasks that one would think of as being routine. We also check how our measures of task codification correlate with those proposed by Spitz-Oener (2006). Employees and occupations which report high intensity of explicit and/or repetitive tasks tend to report significantly fewer tasks such as calculating, bookkeeping, correcting text and data. Therefore, our measures of codifiable tasks capture the *manual* rather than the cognitive routine work. The trends in the use of mathematics, statistics and arithmetic are captured by a separate variable and presented below. Other tasks that we can follow consistently over a longer period of time are: process improvement, educating, and the use of law. A more detailed description of these variables can be found in table 9 in appendix A.

Besides the measures of codification, we also try to capture what Autor, Levy, and Murnane (2003) call nonroutine tasks. When adequate we use original variables from the Qualification and Career Survey. However, in some instances it is useful to have more generic measures of nonroutine

tasks. To create such measures we use factor analysis which is explained in appendix B in detail. Basically, through analysis of the common variance of a group of task measures we reduce their dimensionality to few variables that capture most of the information contained in the original variables. The factor analysis of 14 variables in the 1979 wave results in three factors. The first factor loads high (above .5) on the following variables: research, evaluate, investigate; negotiate, represent; coordinate, organize, delegate; process improvement; arithmetic, math and statistics, and management. We call this abstract dimension. The second factor scores high on: negotiate, consult (customers/suppliers); negotiate, represent; and marketing, sales. We refer to this as the sales dimension. The third factor scores high on: taking care of others and medical examination, cosmetology. We call this the care dimension. Occupations that score highest on the first factor are engineers, entrepreneurs and managers; occupations that score highest on the second factor are salespersons, commercial agents, tourism specialists and restaurant and hotel proprietors; and occupations who score highest on the third factor are nurses, medical and nonmedical practitioners, and social workers.

### **3.3 IAB Employment Samples**

The second source of data we use is the IAB Employment Samples Regional file 1975-2004 (IABS Regional), which is a 2% random sample of the German population subject to social security. As this sample is explained in details in Drews (2008), we only mention its most important features here. The sample does not contain information on employees who are not subject to social security. This affects civil servants and the self-employed. However, for the rest of the employees it is the largest and probably the most reliable source of employment information in Germany. Furthermore, the social security wage data is the most accurate information on wages in

Germany because non-reporting or false reporting is punishable by law. Wages are right-censored and this affects up to 14% of our observations in some years. We implement a wage imputation technique introduced by (Gartner 2005) in order to generate the missing information.<sup>5</sup> We consider Western Germany specifically because for this part of Germany we have a longer time dimension and because earlier waves of the Qualification and Career Survey also only included information on former West Germany. The IABS Regional and the Qualification and Career Survey are matched at the occupational level. Although the survey data has a very detailed (in some waves 4-digit level) occupational classification, the IABS Regional offers an occupational classification between the 2- and the 3-digit level. We drop houseworkers, interns and volunteers. We also drop occupations that in the Qualification and Career Survey list fewer than 10 observations or are not observed in all five waves<sup>6</sup>. This leaves us with 115 occupations we consider in the analyses that involve merging of the datasets. One convenient feature of both the IABS Regional and the Qualification and Career Survey is that they keep a consistent occupational classification system comparable both between the samples and over time.

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<sup>5</sup>The wage prediction is conducted separately for each year. The method used is a tobit regression. For the prediction we include the following variables: age, age squared, education, gender, occupational dummies and 16 industry dummies. These can explain between 19% and 50% of the total individual-level wage variation in separate years.

<sup>6</sup>Spitz-Oener argues that the occupations that disappear from the Qualification and Career Survey or appear for a first time can be considered as a random draw (p. 266 f.)

## 4 The relationship between wages and employment

Autor, Katz and Kearney (2006, Figure 3) show that the relationship between the skill level as measured by the educational achievement<sup>7</sup> and the change in the employment share of occupations shifted from monotonically increasing in skills/earnings in the 1980s to a U-shaped relationship in the 1990s. Goos, Manning, and Salomons (2009) find that the job polarization in 16 European countries is a phenomenon of the 1990s. Contrasting these results, Dustmann, Ludsteck, and Schönberg (2009, p. 871) suggest that the pattern of polarization was present in Germany also in the 1980s. Our observations confirm those of Dustmann, Ludsteck, and Schönberg (2009). Table 2 presents the results of OLS estimations where the 5-year log employment share changes are regressed on the median occupational daily wage. We estimate the same models for 5-year periods starting in 1975, 1977, 1979, 1981, 1983, 1995, 1997 and 1999. We avoid the years that are close to the German Reunification in order to mitigate any shocks to the employment structure that it may have caused. The first specification (Linear fit) shows the results of fitting a model that assumes a linear relationship between wages and employment share changes, while the second specification (Quadratic fit) allows for a nonlinear relationship. We first compare the coefficients of the median occupational wage for the linear specification and find that they almost monotonically decrease over the observed period. In the 1990s the relationship is statistically insignificant. Moreover, when we compare the

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<sup>7</sup>Both occupation-specific educational attainment and the occupational standing on the wage distribution are used as an indicator of the job quality or the skill level (see Autor, Katz and Kearney (2008, p. 191) and compare with Goos and Manning (2007, Figure 1) and with Dustmann, Ludsteck, and Schönberg (2009, Figure VII). We will use the occupational standing in the wage distribution because of the limited quality of our education variable.



linear specification to the quadratic one, we see that the latter notably improves the fit (as measured by the R squared) in six out of eight periods. The U-shaped relationship is not present in the earliest period, 1975-1980, but it is present in both the 1980s and the 1990s, and later on. Despite the presence of a U-shaped relationship between wages and employment growth in Germany, the difference to what has been observed for other developed countries (mainly the U.S. and the U.K.) is that the fast-growing social care-related occupations which in the U.S. and the U.K. accounted for some of the lowest-paid jobs in the 1980s, were already in the middle of the wage distribution in Germany in the late 1970s. Moreover, the declining textile occupations in the thirty years observed were already at the bottom of the wage distribution in the second half of the 1970s. Because both, the declining manufacturing jobs and the growing social care-related jobs, are found in the middle of the wage/skill distribution, its “hollowing out” in Germany is not as pronounced as in other countries.

Table 2: Development of the relationship between employment share growth and the median occupational wage

	1975-80	1977-82	1979-84	1981-86	1983-88	1995-00	1997-02	1999-04
Linear fit								
Median occ. wage	.185*** (.04)	.157*** (.05)	.137*** (.05)	.106** (.05)	.107** (.04)	.041 (.04)	.095 (.06)	.041 (.04)
Constant	-14.86*** (4.24)	-14.07*** (4.93)	-13.60*** (4.98)	-11.25** (4.99)	-1.45** (4.37)	-7.629 (4.81)	-12.20** (5.66)	-7.891* (4.26)
R-squared	.059	.054	.050	.039	.044	.007	.015	.008
Quadratic fit								
Median occ. wage	.140 (.28)	-.459* (.26)	-.622*** (.24)	-.408 (.25)	-.218 (.25)	-.380* (.20)	-.347 (.28)	-.458** (.18)
Median occ. wage squared	.000 (.00)	.003** (.00)	.004*** (.00)	.002** (.00)	.002 (.00)	.002** (.00)	.002* (.00)	.002*** (.00)
Constant	-12.89 (13.13)	13.97 (12.76)	22.74* (11.79)	14.89 (13.11)	5.03 (12.85)	15.75 (11.30)	1.38 (15.09)	17.75 (9.07)
R-squared	.060	.080	.102	.070	.058	.037	.027	.050
Observations	115	115	115	115	115	115	115	115

Source: IABS Employment Samples 1975-2004; OLS results; dependent variable: 5-year employment share growth; robust standard errors in parenthesis; significant at: \*\*\* 1%, \*\* 5%, \* 10% level;

## Fastest growing and declining occupations

In this section we examine the fastest growing and declining occupations in the pre- and post-reunification periods in West Germany. We would like to ascertain if they have anything in common and how they compare with findings in other studies. Table 3 presents the ten fastest growing occupations, while table 4 demonstrates the ten fastest declining occupations in the periods 1975-1988 and 1995-2004. From table 3 we see that besides some highly paid occupations such as management consultants, engineers, physicians and data processing specialists, some low-paid service occupations such as restaurant and bar keepers, catering personnel, medical receptionists, and nonmedical practitioners show the highest employment increases. At the same time, in line with what was mentioned before, fast-growing occupations in the middle of the wage distribution were home wardens and social work teachers, social and care workers, work and vocational advisers. This is in particular true of the pre-reunification period.

Among the fastest declining occupations we find those related to the clothing production, (spinners, fiber preparers and braiders, leather makers, and leather processing operatives, cutters, and textile finishers), metal production, (iron/metal producers, melters, drawers, drillers, cutters), and construction (bricklayers, concrete workers, pavers, stucco workers, etc.). Some clerical personnel such as stenographers were also downsized significantly.

The most comparable study to ours is Goos and Manning (2007) for the U.K. The occupational growth patterns in the U.K. are similar to those in Germany (tables 4 and 6 in Goos and Manning, 2007). In particular, this is true when it comes to the ten fastest declining occupations. The U.K.,

Table 3: Fastest growing occupations

Occupation	1975-1988		1995-2004	
	Median occ. wage 1975 (DM)	Employment growth (percentage)	Median occ. wage 1995 (DM)	Employment growth (percentage)
Home wardens, social work teachers	91.47	1.14	177.27	.68
Social-, care workers, work-, vocational advisers	88.66	1.13	93.89	.60
Management consultants, accountants, tax advisers	104.14	1.09	165.25	.54
Non-medical practitioners, masseurs, physiotherapists	85.85	.89	154.25	.45
Medical receptionists	61.92	.84	112.67	.38
Physicians till pharmacists	152.05	.83	101.40	.33
Data processing specialists	116.81	.81	115.23	.32
Electrical engineers	137.31	.73	88.63	.29
Restaurant/inn/bar keepers, hotel proprietors, catering	68.96	.70	135.95	.29
Economic and social scientists, statisticians	105.55	.69	87.13	.26
Median wage in 1975	87.25		107.41	

Source: IAB Employment Samples 1975-2004

Table 4: Fastest declining occupations  
1975-2004

1975-1988 Occupation	Median occ. wage 1975 (DM)	Employment growth (percentage)	Occupation	Median occ. wage 1995 (DM)	Employment growth (percentage)
Spinners, fiber preparers till braiders	67.55	-.56	Concrete workers	115.67	-.79
Iron/metal producers, melters till metal drawers	9.07	-.47	Miners till Mineral preparers, mineral burners	114.17	-.73
Railway controllers, conductors	88.66	-.47	Bricklayers	113.42	-.59
Leather makers till leather processing operatives	6.51	-.44	Spinners, fiber preparers till Textile processing operatives (braiders)	88.63	-.57
Cutters till textile finishers exp. clothing sewers	56.29	-.37	Cutters till Textile finishers exp. Clothing sewers	71.36	-.52
Wood preparers till basket products makers	74.59	-.27	Leather makers, catgut string makers till Skin processing operatives	80.37	-.46
Drillers till other metal-cutting occupations	92.88	-.25	Paviors till other civil engineering workers	111.17	-.40
Concrete workers	87.25	-.25	Wood preparers till basket and wicker products makers	96.90	-.39
Miners till Mineral preparers, mineral burners	95.70	-.24	Stucco workers, plasterers, rough casters till Screed, terrazzo layers	114.92	-.37
Bricklayers	8.21	-.24	Stenographers, shorthand-typists, typists	102.90	-.37
Median wage in 1975	87.25		Median wage in 1995	107.41	

Source: IAB Employment Samples 1975-2004

however, experienced steeper expansion and downsizing rates than Western Germany in the observed period of time.

## Job quality and wage growth

Goos and Manning (2007) discuss that, contrary to the expectations of higher wage growth at the bottom of the wage distribution - allegedly due to increased demand for “lousy” jobs - the wages of the low paid occupations fell in the U.K. Autor, Katz, and Kearney (2008), on the contrary, evidence that in the U.S. the increase in wages at the bottom of the wage distribution did indeed take place (p. 190).

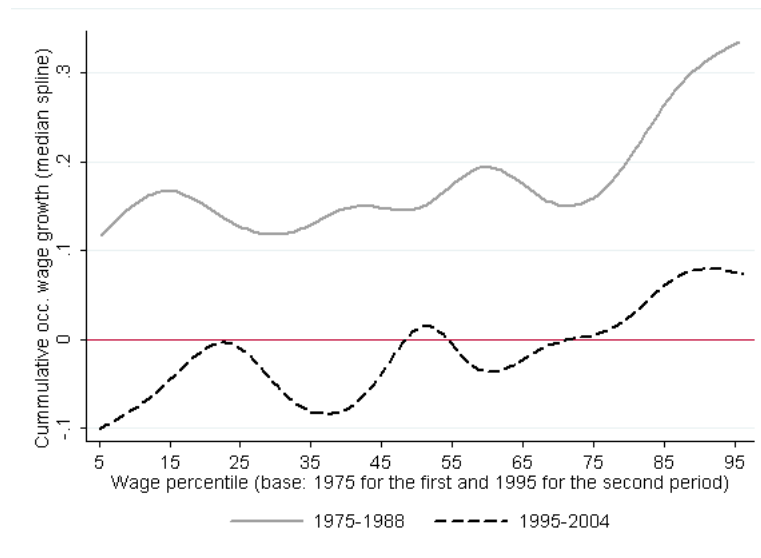


Figure 1: Cumulative changes in the real daily earnings by initial period earnings' percentile

Source: IABS Regional File (1975-2004)

Figure 1 shows the relationship between the job quality measured by its rank in the 1975 and 1995 wage distribution, respectively, and between the

occupational wage growth in the pre-reunification (1975-1988) and the post-reunification (1995-2004) periods. Apparently, as in the U.K. and unlike in the U.S., the real wages of low paid occupations fell in the more recent period.

As Goos and Manning (2007) argue, it is difficult to explain these facts with a theory of technological change that indirectly creates demand shifts for more interactive type of labor (Autor, Katz and Kearney, 2006, p. 193). Moreover, it is difficult to reconcile these observations with any theory that only considers the demand-side factors. A simultaneous increase in employment and wage decline can be encountered under conditions of outward shift of the supply curve. There are reasons to believe that there were supply push factors in the development of services. If automation and computerization truly released labor from the manufacturing sectors, a surplus of labor might have contributed to the expansion of the cheap-services sectors. Subsection 6.2 checks the plausibility of such scenario.

In summary, similar to Dustmann, Ludsteck, and Schönberg (2009) we find that the hollowing out of the middle of the skill/wage distribution was present both in the 1980s and the 1990s in Germany. However, since some declining manufacturing occupations were already low paid in the 1970s and some service occupations were already medium-paid in the 1970s, in Germany the job polarization picture is not as clear-cut as in other developed countries. Additionally, the simultaneous presence of declining wages and increased demand for many service jobs urges for an explanation.

## 5 Tasks: Composition and changes

So far we addressed the relation between wages (chiefly as an indicator of job quality) and employment growth of occupations in order to establish

the fact that the employment prospects mainly declined for the middlepaid occupations. In this section we analyze the task content of occupations in order to understand the commonalities that declining and growing occupations share in terms of task content.

### **Within and between changes in task intensities**

The aggregate changes in task quantity come from three sources: total employment growth of the economy, task intensity shifts within occupations, and changes in the occupational mix of the economy. We are mainly interested in the task changes that stem from the within- and the between-occupational task shifts. To illustrate what these types of changes mean, let us take the occupation of 'turner' in the metal production as an example. The primary task here is the production and finishing of machine components through movements such as turning, drilling, grinding, and molding.<sup>8</sup> The employment share of this occupation in the total employment decreased from .7% to .4% (between-occupational employment change), and the employment decreased by 24% in the period 1979-2005.<sup>9</sup> However, a higher percentage of employees in this occupation report use of explicit work in 2005 than in 1979 (within-occupational task change). Hence, the aggregate codifiable task quantity of this occupation in the economy increased due to the within-occupational upgrading of such tasks

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<sup>8</sup>The occupation of 'turner' has existed in Germany since 1939. Before the introduction of computerized numerical control (CNC) in the 1970s and the 1980s, its work operations were semi-automatized. The introduction of CNC radically changed its occupational content from manual work toward computer programming. In 2002 due to changes in the task content, the occupational training and the occupation itself were also officially re-structured. This occupation now carries the name of 'precision machinist' and is also commonly known as CNC turner.

<sup>9</sup>The estimates are based on the Qualification and Career Survey, waves 1979 and 2005/2006.



and decreased as a result of its diminishing share within the total employment.

Spitz-Oener (2006) evidences a pronounced shift in the frequency of use of different tasks over the period 1979-1999. She finds that the use of analytical tasks on average grew by .5 percentage points, the use of interactive tasks increased by 1.3 percentage points, while the routine cognitive and the routine manual tasks experienced an average annual decline of .7 percentage points in the observed period (p. 244). Due to the shortcomings of the previously used measures of routinization as outlined in subsection 3.2, we revise these findings by using alternative specifications of tasks.

In the rest of this section we describe the development of task intensity between and within occupations. The descriptive analysis is followed by a shift-share analysis that disentangles the change in tasks due to within-occupational shifts from the change due to shifts in the occupational structure of the economy. Table 5 lists the overall changes in the mean occupational tasks reporting for seven tasks that we found to be strictly comparable over at least four survey waves. In contrast to what Spitz-Oener finds, using the generic measures of task codification we find a general trend of increased rather than decreased upgrading of within-occupational manual codifiable tasks (average annual increase in repetitive tasks of .62% and annual average increase in explicit tasks of .55%). The use of arithmetic, math and statistics as a measure of cognitive codifiable tasks shows a pronounced decline in the observed period (an annual decline of 1.18% over a period of 27 years, while some interactive tasks (educating) and cognitive tasks (interpreting laws and regulations and improving processes/trying out new things) gained in overall presence within occupations.

Table 5: Annual percent changes in the use of tasks

Task	Overall annual changes
Repetitive tasks	.62
Explicit tasks	.55
Arithmetics/math/statistics	-1.18
Educate/teach	.51
Interpreting laws/regulations	.70
Process improvement/new things	1.55

Source: Qualification and Career Survey, all waves  
Notes: The changes in educate, teach cover the period 1985-1999. "Arithmetics, math and statistics" is absent in 1985.

As mentioned at the beginning of this section, besides the within-occupational shifts, an important source of changes in the aggregate task measures may come from the transformations in the occupational structure of an economy. In order to glance the trends in the occupational structure changes we categorize all occupations according to three groups: codifiable task dominated, abstract task dominated and interactive task dominated<sup>10</sup>. This categorization is based on the information from the 1979 wave. Figure 2 shows the development of the employment shares of these three groups in the years 1975-2004.

<sup>10</sup>Codifiable tasks dominated occupation is an occupation ranked higher at at least one of the codification measures than on the abstract dimension and the interactive dimension. At the same time it is ranked not lower than the mean rank at one of the codification measures. Accordingly, abstract (interactive) tasks dominated occupation is an occupation that ranks at least at the mean of the abstract (interactive) dimension, and ranks higher on the abstract (interactive) dimension than on the interactive (abstract) one, and higher than or equal to the one of the codifiable measures. In a case of same ranking on both, the interactive and the abstract dimension, an occupation is classified as abstract tasks dominated.

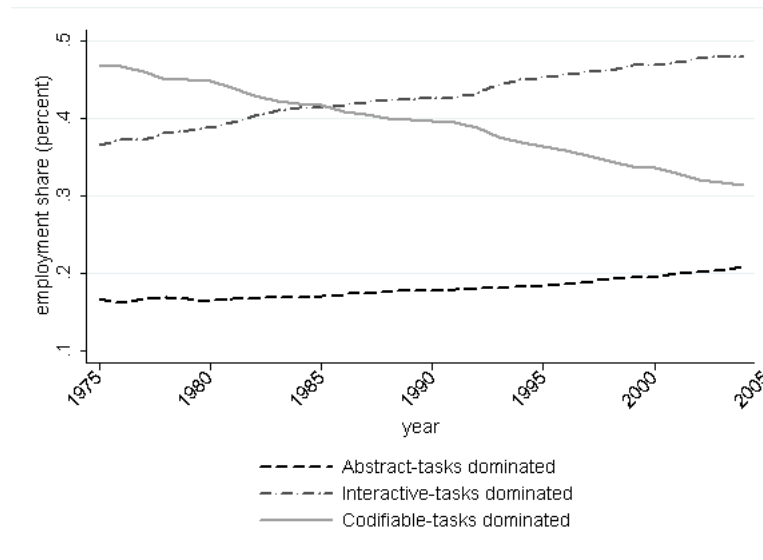


Figure 2: Figure 2: Development of the employment shares  
 Source: IAB Employment Samples 1975-2004

Evidently, there has been a drastic change in the occupational structure of occupations over time. While the interactive and abstract task dominated occupations increased their share in the economy from 36.5% to 47.8% and 16.6% to 20.9%, respectively, the codifiable task dominated occupations decreased their share from 46.8% to 31.3%.

Now we turn to the shift-share analysis. This exercise serves to compare the magnitude and direction of the changes in the total task quantity due to within-occupational upgrading with the task quantity shifts due to the changes in the occupational portfolio of the economy. We follow Spitz-Oener (2006, p. 249) in this respect. Therefore, we decompose the aggregate change in the use of task  $j$  into a term which reflects the changes between occupations and a term which reflects the changes within occupations:  $\Delta T_{jt} = \sum_o (\Delta E_{ot} \bar{t}_{oj}) + \sum_o (\Delta t_{ojt} \bar{E}_o)$ . Here  $T$  is the total task quantity of type  $j$ ;  $E$  is employment of occupation  $o$ ; and  $t$  is the task

quantity of occupation  $o$ ;  $o = 1, \dots, 115$ ,  $t = 1985, 1991, 1998$  and  $2005$ ,  $j =$  explicit-, repetitive tasks, arithmetic/math/statistics, educating, use of law and process improvement. Figure 3 compares the within- and between-occupational task changes in the period 1979-2005/2006.

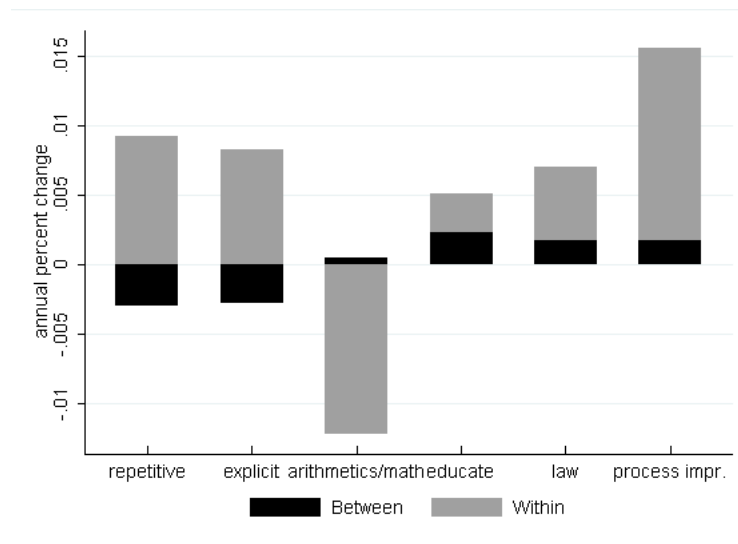


Figure 3: Comparing the size and the direction of within- and between occupational task changes

Source: Qualification and Career Survey, all waves; Notes: See table 5

Figure 3 shows that the within-occupational task changes account for the largest share in the overall changes. It further shows that the between changes do not necessarily take the same direction as the within changes. In the case of repetitive and explicit tasks, the share of employees who report instances of such tasks increased, while the share of occupations with high intensity of repetitive or codifiable tasks decreased in the employment structure. The opposite is the case with occupations which report use of arithmetic, math and statistics.

The observation that employees report more of what we refer to as codifiable task content today than thirty years ago seems to contradict what has earlier been reported for Germany (see, e.g., Spitz-Oener 2006). There are (at least) two possible explanations for the pattern we observe. First, if technology substitutes for certain tasks, the variety of tasks in the task portfolio of a job will decrease, which may lead employees to perceive higher monotonicity in their work activities. Second, over time, through active operations management, the work content within occupations probably becomes more structured and explicit. To decide which explanation is more plausible it would be useful to know whether it is occupations with low initial explicit content that show steeper growth of such content, or whether it is occupations with low initial explicit content that report an upgrading of codifiable tasks. A test of absolute convergence suggests that it is the occupations with high initial levels of codifiable content that show higher increases in such content ( $\beta = .18, t = 6.38, N = 456$ ).<sup>11</sup> This suggests that the first proposed explanation cannot be ruled out. It further suggests that there may be a high concentration of codification advances in certain occupations.

## 6 Making the link: Knowledge codifiability and job polarization

Goos and Manning (2007) argue that the hollowing out of the wage distribution can be explained by the nuanced theory of SBTC proposed by Autor, Levy, and Murnane (2003). While these authors make the link between knowledge codification, computerization, and the decline of jobs with such a content, Goos and Manning observe that jobs with routine task

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<sup>11</sup>The calculation of  $\beta$  or absolute convergence is the following:  $\ln T_{t+1} - \ln T_t = \alpha + \beta T_t + \varepsilon$ , where  $T$  is the share of employees within an occupation that report use of certain tasks, in our case explicit tasks (see Sala-i-Martin 1990, for a definition of  $\beta$  convergence).

content are mainly located in the middle of the wage distribution. using wage information from the 1979 IABS Employment Samples wave and task information from the 1979 Qualification and Career Survey wave we plot the task intensity by occupation (N=115) along the wage distribution. The task intensity measures are standardized to have mean zero and standard deviation of one. From figure 4 we see that occupations which score high on the abstract tasks dimension are found at the higher wage deciles. Occupations which score above average on the sales dimension are found among the worse and the best paid occupations.

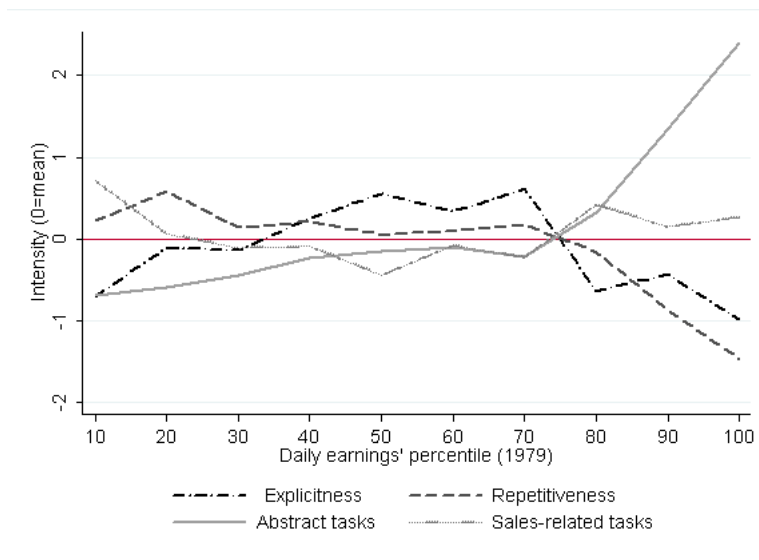


Figure 4: Tasks' intensities along the wage distribution  
 Source: IABS Employment Samples and Qualification and Career Survey, 1979

As explained in subsection 3.2., the factor analysis additionally provides a care-for-others dimension that does not take a very distinct shape along the wage distribution, but may help us understand why some occupations close to the middle of the wage distribution also grew in the observed period. For completeness we include it in figure 6 in appendix B. Probably the most

interesting observation is that the occupations close to the middle of the wage distribution score above average on the explicit tasks measure and below average at the lowest and the highest wage deciles. This is not the case with the measure of task repetitiveness. Here worse paid occupations score higher than middle paid occupations.

We conclude that the occupations with high explicit task content are concentrated in the middle of the wage distribution, while occupations with nonroutine cognitive (abstract) task content are concentrated at the top. Occupations making high use of interactive tasks such as caring for others can be found at different points of the wage distribution, while occupations that report frequent use of sales-related tasks occupy the bottom and top of the wage distribution. Lastly, occupations that report high frequency of repetitive tasks are clustered around the left wage distribution tail. These observations suggest that the decline of employment mainly in the middle of the wage distribution co-occurs with the location of jobs with high explicit tasks' content and not necessarily those with high task repetitiveness. Nevertheless, this may be a coincidence.

## **6.1 Knowledge codifiability and job security**

In section 5 we showed that the share of occupations with frequent use of codifiable tasks decreased in the observed period. It would be useful to check whether the relationship between task content and job security holds at the individual level. At this level we can control for relevant individual-specific factors such as education, age, and gender. All these have been previously found to play a role in changes in the occupational structure (see, e.g., Goos and Manning 2007). At this level we can also identify the industry where a person is employed.

Our dependent variable, perceived layoff risk, is an ordinal one. The most common way to model the relationship between an ordinal dependent variable and a number of independent variables is an ordered logit model.<sup>12</sup> One favorable property of the ordinal logit is that by exponentiating the coefficients, one can obtain the odds ratios. Table 6 presents the results of an ordered probit model, where the perceived layoff risk is regressed on the types of tasks employees perform in their jobs and a number of control variables. Since the coefficients do not have an intuitive interpretation, the odds ratios are reported. An odds ratio over 1 indicates a higher risk for higher values of a dependent variable.

One of the most stable findings is that the explicitness of tasks correlates strongly with a perception of higher layoff risk. This is true for all three waves (1979, 1998/1999 and 2005/2006) and remains stable under different specifications. For example, employees who reported frequent use of explicit tasks in 1998 were 1.6 times more likely to also report a very high layoff risk (in contrast to reporting no risk, low risk, or high risk) *ceteris paribus*. We also see that the repetitiveness of tasks changes sign and is difficult to interpret. Other stable findings are that complex tasks such as educating, organizing and coordinating, improving processes/trying out new things, and managing are associated with a lower perceived layoff risk. Also, the use of arithmetic, math, and statistics is associated with lower layoff risk. This last finding is interesting and in line with what we observe in section 5: although within the same occupations we see a decrease in the use of math, arithmetic, and statistics; occupations that make use of math increased their employment share. One unexpected result is that the instance of research, development, and design activities is associated with higher layoff

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<sup>12</sup>Formally, this model can be written as follows:  $P(Y_i > j) = g(X\beta) = \frac{\exp(\alpha_j + X_i\beta)}{1 + \{\exp(\alpha_j + X_i\beta)\}}$ ,  $j = 1, 2, \dots, M - 1$  where  $M$  is the number of categories in the ordinal dependent variable and  $\beta$  are the coefficients to be estimated.



risk in the later two periods for which we do not have an explanation to this end. Moreover, jobs which involve marketing tasks appear as jobs with low security. This can be explained by the fact that in the advertising sector “the job security depends directly on the agent’s ability to maintain and expand clientele” (Bureau of Labor Statistics 2009, p. 509).

The ordinal logit assumes that the relationship between each pair of outcome categories is the same (proportional odds or parallel regressions assumption). Therefore, although  $M - 1$  models are estimated, the  $\beta$ s do not vary across the equations. We tested whether the assumption of proportional odds is too strong in our models, and we also estimated unconstrained partial proportional odds models (see Peterson and Harrell, 1990; Lall et al., 2002). In all three specifications (1979, 1998/1999, and 2005/2006), we could not reject the proportional odds assumption at the 5% level. At the 10% level we could reject this assumption for the 2005/2006 specification. Since using a less constrained model than the ordinal logit increases the complexity of representation without adding much additional information, we stay with the initial specifications.<sup>13</sup>

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<sup>13</sup>The results of the model tests and the alternative specifications are available from the author on request.

Table 6: Explaining the perceived layoff risk

	1979		1998/1999		2005/2006	
	Model Ia	Model IIa	Model Ib	Model IIb	Model Ic	Model IIc
Codifiable tasks						
Explicitness of tasks	1.660*** (.06)	1.611*** (.06)	1.583*** (.05)	1.574*** (.06)	1.342*** (.05)	1.349*** (.05)
Repetitiveness of tasks	1.175*** (.05)	1.175*** (.05)	.924** (.04)	.934* (.04)	.994 (.04)	.992 (.04)
Mainly abstract tasks						
Organize/coordinate/plan	.696*** (.04)	.713*** (.04)	.782*** (.03)	.793*** (.03)	.938 (.04)	.943 (.04)
Process improvement	.905*** (.03)	.948 (.04)	.833*** (.03)	.839*** (.03)	.895** (.04)	.888*** (.04)
Arithmetic/math/statistics	.839*** (.03)	.894*** (.03)	.909*** (.03)	.918** (.03)	.980 (.04)	1.000 (.04)
Management	.745*** (.04)	.800*** (.05)	.895** (.05)	.920 (.05)	.960 (.04)	.977 (.05)
Research/development/design	.884 (.12)	.868 (.12)	1.236*** (.09)	1.227*** (.09)	1.091** (.04)	1.079* (.05)
Interpreting law/regulations	1.034 (.15)	1.147 (.17)	.830*** (.04)	.873*** (.04)	.940 (.05)	.931 (.05)
Mainly interactive tasks						
Educate/teach	.769** (.09)	.769** (.10)	.750*** (.04)	.756*** (.04)	.924*** (.02)	.912*** (.02)
Medical and cosmetic care	.676*** (.08)	.896 (.14)	.918 (.05)	.921 (.07)	1.107* (.06)	.963 (.08)
Marketing	1.047 (.06)	1.025 (.06)	1.105* (.07)	1.129* (.07)	1.073* (.04)	1.079* (.04)
Sales and customer support	1.019 (.06)	.948 (.06)	.898*** (.03)	.886*** (.03)	.943 (.04)	.953 (.04)
Controls						
Age	.983*** (.00)	.982*** (.00)	.980*** (.00)	.980*** (.00)	.991*** (.00)	.990*** (.00)
Gender	.974 (.04)	1.013 (.05)	.895*** (.03)	.929* (.04)	.944 (.04)	.933 (.04)
Education dummies	yes	yes	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes	yes	yes
Occupation dummies	no	yes	no	yes	no	yes
Log pseudo likelihood	-12,790.1	-12,627.6	-16,660.7	-16,450.6	-12,784.1	-12,664.9
Observations	22,636	22,636	16,595	16,517	12,980	12,932

Explained variable: perceived layoff risk; Ordered logit model; Robust standard errors in parentheses; Odds ratios are reported. Significant at \*\*\*1%, \*\*5% , \*10% level

To further check the robustness of the findings, we used different definitions of our core variables. We tried two alternatives to the original scaling of explicitness and repetitiveness of tasks.<sup>14</sup> The results remain consistent with those presented in table 6.

In section 2 we additionally hypothesized that there might be an interaction between the use of codifiable and interactive tasks when predicting the layoff risk. Some occupations may report a high level of explicit knowledge, but also a high level of interaction with customers, clients or patients. For example, the daily tasks of a butcher or baker may follow a routine procedure, but may also involve a high customer-contact frequency. We expected that when explicit tasks coincide with interactive ones, this would somewhat mitigate the layoff risk. This expectation is not borne out in the data. All the interactions between explicit and interactive tasks are insignificant and this holds for all three waves.

We are further interested to know whether the measure of explicit tasks predicts higher layoff risk for different educational levels. If the earlier view of skill-biased technological change is true, only employees at lower educational levels would fear unemployment. The more nuanced view of SBTC proposes that codifiable knowledge is at risk of technological substitution within groups with identical education. Our results show that the frequent presence of explicit tasks predicts higher layoff risk at different educational levels. Table 7 presents the interactions between the explicitness of tasks and the education dummies separately for each wave. As a reference category in all years we take employees without formal

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<sup>14</sup>The first alternative is defining these variables as dummies, where 0 indicates absence, seldom use or periodical use of the task and 1 indicates frequent or constant use of the task. This is the specification that we report in the tables. In the second alternative, 0 indicates absence or seldom use of the task, while 1 indicates periodical, frequent or constant use of the task.

education who do not report use of explicit tasks. In all three waves and at almost all educational levels, we find that employees who report frequent use of explicit tasks are more likely to be found in the highest layoff risk category in comparison to the employees in the reference group. Most of the time this is not the case with employees who have some formal education but do not report frequent use of codifiable tasks.

Table 7: Explaining the perceived layoff risk: task explicitness-education interactions

1979		
No/unknown education	1.814***	(.14)
Vocational school (Berufsschule)	1.665***	(.08)
Full-time vocational school (Berufsfachschule)	1.433***	(.16)
Master crafts (Meisterschule)/Technical school (Technikerschule)	1.440**	(.24)
Health care school(Gesundheitswesenschule)	2.019**	(.72)
Civil servants' school (Beamtenausbildung)	1.903**	(.56)
Other vocational schools	1.547*	(.40)
Vocational academy (Berufsakademie)/Technical college (FHS)	1.619*	(.44)
University	1.266	(.38)
1998/1999		
No schooling	2.054***	(.20)
Any vocational school or similar	1.525***	(.06)
Master crafts, technical school or similar	1.465***	(.15)
Technical college	1.434**	(.25)
University	1.701***	(.24)
2005/2006		
No schooling	1.400***	(.18)
Vocational training of any kind	1.288***	(.06)
Master crafts, technical school and similar	1.387***	(.17)
Technical college/University	1.507***	(.12)

All specifications and observations same as in Table 6 (Models Ia, Ib and Ic). The schooling classifications differ by wave and therefore are not strictly comparable

Finally, we want to know whether the relationship between task explicitness

and layoff risk differs by industry. This is an important issue as it is well evidenced that automation is not equally advanced in all industries. Automation of explicit tasks such as train driving even today has hardly any impact on labor, while automation in manufacturing should have gone a long way in substituting human effort. Additionally, the private sector may manage labor differently than the public sector. The former should react faster to possibilities to increase productivity than the public one.

In order to analyze the differences, we interact the industry dummies with the variable which indicates presence of explicit tasks. One industry has to be chosen as a reference group: we choose the employees in agriculture and mining who do not report frequent use of explicit tasks. Now we can compare the coefficients for employees in other industries who do not report frequent use of explicit tasks with those of the employees in the same industries who report frequent use of such tasks. Table 8 contains the results of this analysis. What we expect is that, in at least in some industries, employees who report frequent use of explicit tasks also report higher layoff risk. This is indeed the case. First, all significant odds ratios in models II are higher than 1. This is not the case with models I. Also, the odds ratios in models II are consistently higher than those in models I. Across survey waves, the significant differences between the groups with and without frequent use of explicit tasks (see the  $\chi^2$  column) are found in manufacturing, services, public administration and energy, and garbage collection.

We find no significant differences between employees who frequently perform explicit tasks and those who do not in construction, postal service, and railway and road transportation. It is beyond the scope of this study to explain these patterns. With this information we cannot discriminate whether it is the public type of (some of) these sectors or the limitation of

the technology which still makes it difficult to substitute for locomotion-related and building-related tasks that drives the results. Further research in the industry-specific patterns of technological change should provide more informative investigations on this issue.

Table 8: Task explicitness- industry interactions

Industry	Explicit=0		Explicit=1		Test of differences $\chi^2$
	Model I		Model II		
1979					
Manufacturing	1.421***	(.18)	1.699***	(.09)	1.42
Construction	1.598***	(.24)	1.794***	(.19)	.29
Rail- and road transport	1.061	(.29)	1.228	(.35)	.08
Services	1.206	(.16)	1.626***	(.10)	3.76*
Public administration	.512***	(.09)	1.750***	(.31)	15.66***
Energy, garbage collection	.685	(.22)	2.208**	(.82)	3.38*
Post	1.144	(.29)	1.247	(.39)	.03
1998/1999					
Manufacturing	.673**	(.13)	1.534***	(.08)	15.58***
Construction	.949	(.20)	1.458***	(.17)	2.47
Rail transportation	.461	(.28)	1.223	(.78)	.65
Services	.574***	(.11)	1.669***	(.08)	27.09***
Public administration	.278***	(.06)	1.494***	(.18)	39.8***
Energy, garbage collection	.692	(.18)	.994	(.25)	.71
Post	.737	(.20)	1.111	(.31)	.72
2005/2006					
Manufacturing	.856	(.14)	1.298***	(.08)	5.20**
Construction	1.038	(.19)	1.346**	(.19)	.90
Services	.765*	(.12)	1.385***	(.07)	11.73***
Public administration	.470***	(.09)	1.140	(.19)	8.27***
Energy, garbage collection	.469***	(.11)	1.901**	(.49)	1.99***
Post	1.204	(.30)	1.123	(.34)	.02

All specifications and observations and explanations are same as in Table 6 (Models Ia, Ib and Ic).

## 6.2 Note on the service employment growth

In section 4 we show that despite the increasing employment of low-paying occupations, their wages declined. We speculate that this may be due to the labor supply push from sectors where surplus of labor occurred (either due to technological change, outsourcing, or because of other factors). Figure 5 plots the ratio between the total inflow of labor from different sectors into services and the total outflow of labor from services into other sectors. An inflow-outflow ratio of 1 means that the inflow into services equals the outflow from services, while an inflow-outflow ratio of below 1 would mean that the outflow from services exceeds the inflow into services. The mean inflow-outflow ratio for the period until 1990 is 1, meaning that services exchanged around the same quantity of labor force with other sectors on an annual basis. In the period after 1990, the inflow of labor into services increased beyond the outflow in relation to all other sectors. The mean annual inflow-outflow ratio in this period is 1.13, meaning that on average services gained around 13% net labor inflow from other sectors annually. From figure 5 we see that these inflows did not only stem from manufacturing, but also from construction and agriculture, and mining. Although a complete explanation of the decreasing wages for growing occupations will necessitate a good measure of the demand side in services, here we suggest that a labor supply push from other sectors is one likely explanation.

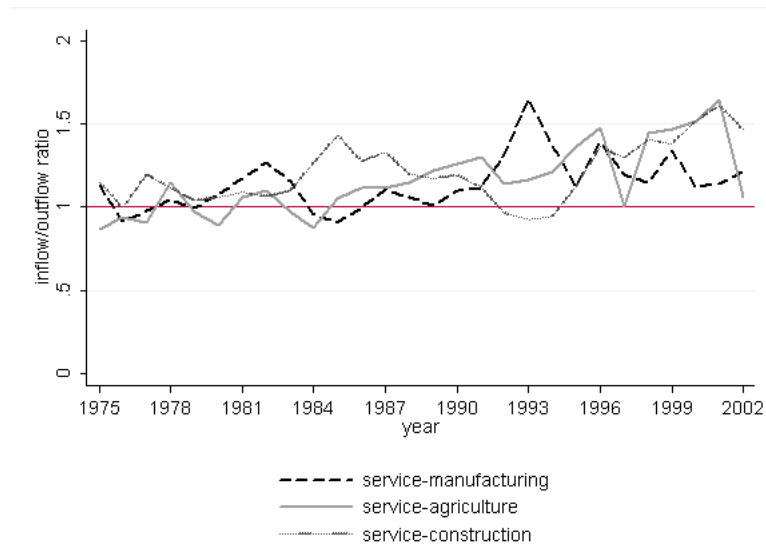


Figure 5: Labor inflow-outflow ratio between services and other sectors  
 Source: IABS Employment Samples 1975-2004  
 Note: the time series is interrupted in 2002 due to change of the industrial classification

## 7 Conclusions

Similar to other developed countries, the occupational structure of Western Germany changed in a salient way in the last few decades. These changes were not necessarily those expected by employment researchers. Earlier research expected that the employment share of occupations would increase proportionally to their job quality. This meant that better paid jobs and jobs with higher educational requirements were expected to increase their employment share at the expense of those with lower job quality. Such anticipation was later justified since many of the top paid occupations were at the same time the fastest growing ones. Nevertheless, an unexpected finding in the recent literature is that the major employment downsizing occurred in the middle paid and not the worse paid occupations. The



leading explanation for this observation is that new advances in technology, in particular computerization, substituted tasks that are highly codifiable. It happened that occupations with highly codifiable tasks were concentrated in the middle of the wage distribution in the period of computer proliferation. Our findings support part of the predictions outlined in this nuanced theory of skill-biased technological change.

We find that high frequency of tasks that can be explained in each and every detail (explicit tasks) correlates with higher layoff risk at the individual level. This is not necessarily the case with tasks of a repetitive nature. The positive correlation between the frequency of explicit tasks and layoff risk holds for employees with different educational levels and for labor in various broadly defined industries. The correlation is independent of the gender and age of an employee and is present in both the pre-reunification and the reunification period in Western Germany.

The reasons why labor with codifiable task content is at higher layoff risk may be multiple. For instance, both computerization of the workplace and international outsourcing of parts of the production process may result in downsizing of such labor. Although some effort is already being made to distinguish such forces (e.g., Goos, Manning, Salomons 2009), further research should be undertaken to disentangle the impact of different factors on occupational structure shifts.

Other stable and consistent findings are that the frequency of cognitive tasks such as educating, organizing and coordinating, improving processes/trying out new things, and managing are associated with lower perceived layoff risk. The relationship between service-oriented tasks such as marketing, sales/customer support, and medical/cosmetic care on one side and job security on the other is ambiguous. The growth of service jobs in the economy does not necessarily translate into their higher security.

We finally offer evidence that the decline in the price of low paid service jobs in the 1990s coincided with a period of labor supply push from manufacturing, agriculture and mining, and construction. Since the low paid service jobs require minimum training, a supply push from other sectors may explain their low job security albeit increased demand for these services.

The findings are relevant for educational and requalification policies. Education should shift the curriculum away from specialized and highly explicit knowledge and foster more general problem-solving curricula.

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## Appendix A

Table 9: List and definitions of variables used

Variable	Original question (wave 1979)	Scale
Strictly comparable questions to other waves		
Explicitness of tasks	Wie oft kommt es bei Ihrer täglichen Arbeit vor, dass Ihnen die Arbeitsdurchführung bis in alle Einzelheiten vorgeschrieben ist?	1-5
Repetitiveness of tasks	Wie oft kommt es bei Ihrer täglichen Arbeit vor, dass ein und derselbe Arbeitsgang sich bis in alle Einzelheiten wiederholt?	1-5
Process improvement	Wie oft verlangt Ihre tägliche Arbeit bisherige Verfahren zu verbessern oder etwas neues auszuprobieren?	1-5
Arithmetic/math/statistics,	Benötigen Sie: Rechnen, Mathematik, Statistik bei Ihrer beruflichen Tätigkeit?	dummy
Use of law	Tätigkeit die in der letzten Zeit bei Ihrer beruflichen Arbeit angefallen ist: Gesetze/Recht anwenden und auslegen	dummy
Educate, teach	Tätigkeit die in der letzten Zeit bei Ihrer beruflichen Arbeit angefallen ist: Erziehen, unterrichten, ausbilden, lehren	dummy
Comparable questions to other waves		
Research/evaluate/investigate	Tätigkeit die in der letzten Zeit bei Ihrer beruflichen Arbeit angefallen ist: Forschen, Auswerten, Erkunden?	dummy
Negotiate, consult	Tätigkeit die in der letzten Zeit bei Ihrer beruflichen Arbeit angefallen ist: Mit Kunden/Anbietern verhandeln, Kunden beraten Tätigkeit die in der letzten Zeit bei Ihrer beruflichen Arbeit angefallen ist: Verhandeln, Interessen Vertreten	dummy
Taking care of people	Tätigkeit die in der letzten Zeit bei Ihrer beruflichen Arbeit angefallen ist: Betreuen, pflegen, versorgen	dummy

Medical examination	Tätigkeit die in der letzten Zeit bei Ihrer beruflichen Arbeit angefallen ist: Ärztlich untersuchen, diagnostizieren	dummy
Coordinate/organize/delegate	Tätigkeit die in der letzten Zeit bei Ihrer beruflichen Arbeit angefallen ist: Koordinieren, organisieren, disponieren	dummy
Marketing, sales	Benötigen Sie: Verkauf, Werbung, Marketing bei Ihrer beruflichen Tätigkeit?	dummy
Management	Benötigen Sie: Betriebsführung, Organization bei Ihrer beruflichen Tätigkeit?	dummy

Source: Qualification and Career Survey, wave 1979

Table 10: Descriptive statistics

Variable	1979					1998/1999					2005/2006				
	Mean	S. D.	Min	Max	Obs	Mean	S. D.	Min	Max	Obs	Mean	S. D.	Min	Max	Obs
Layoff risk	0.24	0.49	0	2	22636	0.84	0.75	0	3	16595	0.78	0.71	0	3	12980
Explicitness	0.42	0.49	0	1	22636	0.52	0.5	0	1	16595	0.46	0.50	0	1	12980
Repetitiveness	0.64	0.48	0	1	22636	0.71	0.46	0	1	16595	0.71	0.45	0	1	12980
Teach, educate	0.04	0.2	0	1	22636	0.12	0.33	0	1	16595	0.69	0.75	0	2	12980
Medicine/cosmetology	0.04	0.19	0	1	22636	0.1	0.3	0	1	16595	0.13	0.34	0	1	12980
Organize, coordinate	0.17	0.38	0	1	22636	0.32	0.47	0	1	16595	0.65	0.48	0	1	12980
Process improvement	0.39	0.49	0	1	22636	0.52	0.5	0	1	16595	0.74	0.44	0	1	12980
arithmetics, math, statistics	0.58	0.49	0	1	22636	0.32	0.47	0	1	16595	0.28	0.45	0	1	12980
Marketing, sales	0.23	0.42	0	1	22636	0.08	0.27	0	1	16595	0.40	0.49	0	1	12980
Management	0.2	0.4	0	1	22636	0.14	0.34	0	1	16595	0.20	0.40	0	1	12980
Customer support	0.18	0.38	0	1	22636	0.55	0.5	0	1	16595	0.65	0.48	0	1	12980
Research	0.02	0.15	0	1	22636	0.04	0.21	0	1	16595	0.34	0.47	0	1	12980
use of law	0.03	0.17	0	1	22636	0.14	0.35	0	1	16595	0.19	0.39	0	1	12980
Age	37.5	11.68	18	65	22636	39.43	10.58	19	64	16595	40.33	10.08	18	65	12980
Gender	1.33	0.47	1	2	22636	1.42	0.49	1	2	16595	1.46	0.50	1	2	12980
Education	0.04	0.2	0	1	22636	0.12	0.33	0	1	16595	0.69	0.75	0	2	12980

Descriptive statistics for the models in section 6

## Appendix B: Factor Analysis

The basic idea behind the use of FA is that the multiple tasks that enter our empirical design can actually be reduced to few dimensions that give us almost the same information as the full set of variables. The resulting factors from FA are orthogonal by construction which is a very favorable feature in multiple regression. The FA can also be confirmatory to the belief that there exist abstract, interactive and codifiable dimensions.

Formally, FA assumes that  $L$  characteristic tasks of occupations can be represented by  $K$  task dimensions, where  $K < L$  without much loss of information. The identification of these underlying dimensions (factors) can be represented with the following set of linear models:

$$(1) C_{ij} = \lambda_{i1}\theta_{1j} + \lambda_{i2}\theta_{2j} + \dots + \lambda_{ik}\theta_{kj} + \varepsilon_{ij}$$

where  $i = 1, \dots, l$  and  $C_{ij}$  is the intensity of task  $i$  for occupation  $j$ .  $\theta_{kj}$  is the amount of the underlying task  $k$  present in occupation  $j$ ,  $\lambda_{ik}$  is the factor loading of task  $j$  on task dimension  $k$  and  $\varepsilon_{ij}$  is an independently distributed error term which may differ in each equation. In this set of models only  $C_{ij}$  are known to us. As evident from the formulation, FA posits that  $C_{ij}$  are a linear combination of  $k$  unobserved factors indicated with the letter  $\theta$  in the above equations. The intercepts of the equations are by construction equal to zero<sup>15</sup>.

The above set of models can be represented in a matrix form:

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<sup>15</sup>On one hand the intercepts are of no interest for the FA purpose, on the other it is not possible to estimate both the factor loading and the intercept simultaneously (e.g. Bollen 1989).



$$(2) \mathbf{c}_j = \mathbf{\Lambda}\boldsymbol{\theta}_j + \boldsymbol{\varepsilon}_j,$$

where  $\mathbf{c}_j$  is  $l$  by 1 vector of observed variables,  $\mathbf{\Lambda}$  is an  $l$  by  $k$  matrix of factor loadings,  $\boldsymbol{\theta}_j$  is a  $k$  by 1 vector of underlying factors, and  $\boldsymbol{\varepsilon}_j$  is a  $l$  by 1 vector of measurement errors. We can stack equation (2) over occupations and drop the index  $j$  which yields:

$$(3) \mathbf{C} = \mathbf{\Theta}\mathbf{\Lambda}' + \mathbf{E},$$

where now  $\mathbf{C}$  is a  $n$  by  $l$  matrix of observed variable values,  $\mathbf{\Theta}$  is an  $n$  by  $k$  matrix of scores of the underlying factors,  $\mathbf{\Lambda}'$  is the transpose of an  $l$  by  $k$  matrix of factor loadings and  $\mathbf{E}$  is an  $n$  by  $l$  matrix of measurement errors.

The only input that enters the factor analysis is the matrix  $\mathbf{C}$ . In fact, all the information necessary for the estimation of  $\mathbf{\Theta}$  and  $\mathbf{\Lambda}$  is the covariance matrix of the observable variables. In order to identify these matrices we necessitate certain assumptions:

$$(4a) E(\mathbf{E}'\mathbf{\Theta}) = E(\mathbf{\Theta}'\mathbf{E}) = 0$$

$$(4b) E(\mathbf{E}'\mathbf{E}) = \mathbf{\Delta}_e$$

$$(4c) E(\mathbf{\Theta}'\mathbf{\Theta}) = \mathbf{\Phi}$$

$$(4d) E(\mathbf{C}'\mathbf{C}) = \mathbf{\Sigma},$$

where  $\mathbf{\Phi}$  is a  $k$  by  $k$  variance-covariance matrix of the underlying factors,  $\mathbf{\Sigma}$  represents the  $l$  by  $l$  variance-covariance matrix of the data and  $\mathbf{\Delta}_e$  is an  $l$  by  $l$  variance-covariance matrix of the errors. Under these assumptions we can rewrite (3) as:

$$(5) \Sigma = \Lambda\Phi\Lambda' + \Delta_e$$

This means that the variances and the covariances among the observed variables can be decomposed into a component attributable to the underlying factors and a component attributable to the variances and covariances of the measurement errors. Because the number of unique elements in (5)  $l(l+1)/2$  is still larger than the number of elements that need to be estimated  $lk + k(k+1)/2 + l(l+1)/2$ , two further constraints need to be made in order to make (5) identifiable. One constraint is that  $\Phi$  is identity matrix (which results in factors that are orthogonal among each other and with variance 1). The second one is that  $\Delta_e$  must to be diagonal.

using the notation from equation (5),  $\Sigma$  is the variance-covariance matrix of the variables listed in table 9.

The 14 variables resulted in three factors that had eigenvalues above one. The eigenvalues measure the variance in all variables that is accounted by a factor. As a rule of thumb factors with eigenvalues of at least one are considered to explain non-trivial amount of the total variance in the data. In the 1979 wave these three factors have eigenvalues of 5.4, 1.75 and 1.27 and together explain 94% of the total variance in the 14 variables. Based on the factor loadings on different variables and the occupational rankings on each of these factors we interpret the first one as abstract dimension, the second one as sales dimension and the third one as the care dimension. Table presents the factor loadings.

Table 11: Factor loadings

Variable	Abstract skills	Sales-related	Care-related	Uniqueness
Research, evaluate, investigate	.74			.45
Negotiate, consult use of law	.49	.94		.11 .76
Taking care of people			.78	.38
Medical examination/cosmetology			.75	.44
Negotiate, represent	.58	.59		.31
Coordinate, organize, delegate	.91			.14
Process improvement/try out new things	.73			.42
Explicitness of tasks	-.43	-.47	-.31	.51
Repetitiveness of tasks	-.68			.44
Arithmetic/math/statistics	.65	.38		.40
Marketing, sales		.96		.04
Management	.79	.44		.19

Source: Qualification and Career Survey, 1979 wave. N=115. Results of a factor analysis after rotation. Only loading of .3 or higher are displayed.

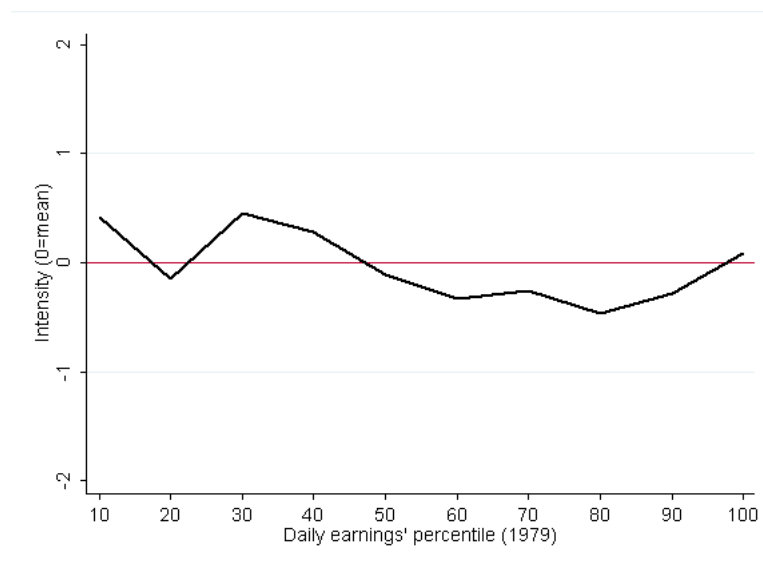


Figure 6: Care-for-others intensity along the wage distribution  
IABS Employment Samples and Qualification and Career Survey, 1979  
Note: Care-for-others is a factor from a factor analysis. It takes a mean of zero and a std.dev. of one.