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Skill-biased technical change vs. structural change: Insights from a new view of the structure of an economy

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Kiel Working Papers

Kiel Working Paper No. 868

Skill-Biased Technical Change
Vs. Structural Change

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Insights From A New View of the Structure of an Economy*

by

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SKILL-BIASED TECHNICAL CHANGE VS. STRUCTURAL CHANGE

Insights From A New View of the Structure of an Economy*

by

Axel Schimmelpfennig

July 1998

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Abstract

Skill-biased technical change is identified as the driving force behind the changing skill composition in OECD countries rather than structural change. The finding is partly the result of the sectoral view taken. This paper suggests a different view which uses the production process as a starting point. The economy is divided into physical production, personal services, and intermediate services; these branches are again subdivided. Applying the resulting grid to German data from the Socio-economic Panel shows that a structural change in the production process is driving the skill composition of the German labor force.

*JEL Classification: E24 (Employment, Unemployment Wages)
J21 (Labor Force and Employment, Size,
and Structure)*

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*"... the rapid diffusion of ICT [information and communication technology] has led – and continues to lead – to a substantial 'exclusion' of large parts of the labour force, either unskilled or wrongly skilled and incapable of training."*¹

1 Introduction

There has been a secular shift in relative labor demand towards more skilled workers in all industrialized countries since the eighties (cf. Nickell, Bell 1995 and 1996). In most empirical research this is attributed to a skill-biased technical change (cf. Krugman 1996: 37). In other words, the shift is not explained within any model, but as a residual called technical change which "... is simply a label for our ignorance." (Gottschalk and Smeeding 1997: 649).

Two rivaling hypothesis are offered for the change in relative labor demand. According to the sectoral structural change hypothesis, relative labor demand changes because the sectoral structure of the economy changes: Expanding sectors have a higher skill-share than shrinking sectors. Sectoral structural change can be driven by demand side factors like trade or by differences in productivity growth on the supply side. According to the skill-biased technical change hypothesis, technical change leads to a substitution of skilled workers for unskilled workers within all sectors of the economy.

The empirical test of the structural change hypothesis vs. the skill-biased technical change hypothesis is in many cases conducted as a shift-share analysis applied to a sectoral decomposition of the economy under investigation. This paper argues that it is the sectoral view of the economy, which is responsible for the finding of skill-biased technical change. The sectoral view is inadequate to describe the structural change that the production process in all industrialized economies is presently undergoing: It is not only that existing jobs are

¹ Freeman et al. (1995: 600).

filled with skilled workers instead of unskilled workers. Rather, new occupations are created that require more skilled workers than the old occupations that are phased out. Therefore, a different view is needed that explicitly considers this change. The view will be derived by structuring the economy according to the different stages of the production process: physical production, personal services and intermediate services. Applying the view to German data reduces the influence of skill-biased technical change significantly.

It is important to understand the actual forces that drive relative labor demand. In the short-run, labor supply will most likely not keep up with changes in labor demand. Unemployment or increasing wage differentials will result. In the long-run, labor supply can adapt to changes in labor demand by acquiring new skills. This will be facilitated, if we know what type of new skills will be demanded. Hence, a thorough understanding of the fundamental changes in the economy is necessary.

The remainder of the paper is organized as follows. Section 2 attempts a somewhat formal definition of skill-biased technical change. Section 3 provides a selective survey of the literature that will lead to the suggested new view of an economy. Section 4 describes this production process grid in detail. Section 5 applies both the sectoral and the production process grid to Germany on the basis of the German Socio-economic panel (GSOEP). Section 6 summarizes the main findings and proposes ways for future research.

2 Defining Skill-Biased Technical Change

Although skill-biased technical change (SBTC) is widely used in the literature, it is usually not defined in a precise manner. In general, SBTC is understood to describe a kind of technical change that leads to an increase in the demand for skilled workers and to a fall in the demand for unskilled workers. However, if capital and skilled labor are complements while capital and unskilled labor are substitutes, a

mere capital deepening will show up as SBTC in the data, because it will lead to a shift in relative labor demand.

Johnson (1997) relates SBTC to different forms of innovations. He defines intensive SBTC as a technical change that makes skilled workers more productive in the jobs they already perform; the introduction of computers is an example. Extensive SBTC is defined as a technical change that leads to the employment of skilled workers in jobs that were formerly performed by unskilled workers; the use of robotics in manufacturing is an example. Technical change is skill-neutral, if it raises the productivity of all workers by the same percentage. Also conceivable is the existence of unskilled-biased technical change, e.g. the introduction of the assembly line in production.

Katsoulacos (1986) proposes two types of innovation each having a different influence on employment: (i) Process innovation decreases employment by mainly eliminating jobs for the unskilled, while (ii) product innovation increases employment by creating new jobs that often require skilled workers. Both types of innovation can appear as SBTC in the data. However, one should bear in mind that product innovation is better described as sectoral structural change, because it leads to the rise of new markets. The distinction between SBTC and sectoral structural change is therefore not as clear cut as it appears on first sight.

In the literature on economic growth three neutrality concepts are discussed when investigating the influence of disembodied technical change² on the production factors labor and capital (cf. Barro and

² Disembodied technical change increases the productivity of the production factors. Taking two extreme cases, either a constant output can be produced using less inputs, or a higher output can be produced using constant inputs. Technical change affects both relative and absolute factor demand. Embodied technical change would come in the form of a new capital stock (vintage approach). Whereas disembodied technical change leaves the production factors themselves unchanged, embodied technical change makes them more

Sala-i-Martin 1995: 33): Hicks-neutral technical change, Harrod-neutral technical change, and Solow-neutral technical change. Technical change influences a factor's income share: (i) Labor saving technical change lowers the wage share; (ii) Capital saving technical change raises the wage share; (iii) Neutral technical change leaves the wage share constant. To study the effect of technical change on the wage share in comparative statics, the three concepts hold some other measure constant.

Output Y is produced with a linear homogeneous production technology F , using unskilled labor U and skilled labor S . Firms maximize profits. All markets are perfectly competitive. The income share of unskilled labor is given by

$$s_U = \frac{wU}{Y} = \frac{F_U U}{Y} = 1 - \frac{rS}{Y} = 1 - \frac{F_S S}{Y} \quad (1)$$

where w is the wage rate of unskilled labor and r is the wage rate of skilled labor. Subscripts indicate first derivatives. If the income share of unskilled labor is unchanged by technical change, the ratio of factor incomes is also unchanged.

$$\frac{\partial s_U}{\partial T} = 0 \Leftrightarrow \frac{\partial \frac{F_U U}{F_S S}}{\partial T} = 0$$

where T is the working of technical change.

Hicks-neutrality is given, if the ratio of the marginal products of unskilled and skilled labor stays constant for a given unskilled-skilled labor ratio.

heterogeneous. Hercowitz (1998) provides a survey of the embodiment controversy.

$$\frac{\partial \frac{F_U}{F_S} \Big|_{\frac{U}{S} = \bar{\frac{U}{S}}}}{\partial T} = 0 \quad (2)$$

where a bar over a fraction indicates that this fraction stays constant.

Technical change is skill-biased in the Hicks-sense, if the ratio of the marginal products of unskilled and skilled labor falls for a given unskilled-skilled labor ratio.

$$\frac{\partial \frac{F_U}{F_S} \Big|_{\frac{U}{S} = \bar{\frac{U}{S}}}}{\partial T} < 0 \quad (3)$$

Harrod-neutrality is given, if the marginal product of skilled labor stays constant for a given skilled labor-output ratio.

$$\frac{\partial F_S \Big|_{\frac{S}{Y} = \bar{\frac{S}{Y}}}}{\partial T} = 0 \quad (4)$$

Technical change is skill-biased in the Harrod-sense, if the marginal product of skilled labor rises for a given skilled labor-output ratio.

$$\frac{\partial F_S \Big|_{\frac{S}{Y} = \bar{\frac{S}{Y}}}}{\partial T} > 0 \quad (5)$$

Solow-neutrality is given, if the marginal product of unskilled labor stays constant for a given unskilled labor-output ratio.

$$\frac{\partial F_U \Big|_{\frac{U}{Y} = \bar{\frac{U}{Y}}}}{\partial T} = 0 \quad (6)$$

Technical change is skill-biased in the Solow-sense, if the marginal product of unskilled labor falls for a given skilled labor-output ratio.

$$\frac{\partial F_U \Big|_{\frac{U}{Y} = \bar{\frac{U}{Y}}}}{\partial T} < 0 \quad (7)$$

Taking the neutrality concepts together, SBTC is associated with a fall in the ratio of the marginal product of unskilled to the marginal product of skilled labor if the economy stays at full employment. By definition, the wage share of unskilled labor falls.

$$\frac{\partial \frac{F_U}{F_S}}{\partial T_{SB}} < 0 \quad (8)$$

To sum up the discussion, a working definition of SBTC is: Technical change is skill-biased, if it leads to a fall in unskilled labor's income share after controlling for changes in the skill-composition of labor supply. In flexible labor markets, SBTC increases the wage differential between unskilled and skilled labor. In non-flexible labor markets, SBTC increases unemployment among the unskilled, while unemployment among the skilled remains unchanged.

3 A Selective Survey of the Literature

The empirical literature has produced two diverging stylized facts across OECD labor markets. In countries like the United States or the United Kingdom, wage differentials have increased, with especially the low skilled suffering real wage losses. In countries like Germany or France, unemployment has risen, again with especially the low skilled being affected. Krugman (1995) regards these diverging developments as two sides of the same coin: Labor demand has shifted from the unskilled to the skilled. In countries with flexible labor markets, wages reacted. In countries with non-flexible labor markets, unemployment rose.

There appears to be a wide consensus in the empirical literature of what drives the skill composition of the labor force in industrial economies: skill-biased technical change (SBTC). This view is arrived at in three steps. First, it is shown that the change in the skill composition is not brought about by the change in relative labor supply. Second, a shift-share analysis is used to show that changes in the sectoral structure of the economies account for only one third of

the change in the skill composition. Third, SBTC is identified as the major factor driving the skill composition, as the shift is observed within every sector. This conclusion is sometimes supported by regression analysis of the skill-composition on technology variables like use of computers as explanatory variables. However, in many cases, the empirical findings can also be interpreted as evidence for a structural change of the production process. Table 1 provides a far from exhaustive survey of the literature.³

Katz and Murphy (1992) use the Current Population Survey to study the skill composition in the United States from 1963 to 1987. The U.S. economy is divided into 50 two-digit industries and three occupational categories. They find that between industry changes account for 30 percent of the change in the skill composition. Within industry changes therefore explain most of the change; SBTC drives the skill composition of the U.S. labor force. The results can also be viewed from a slightly different angle: There is a shift towards more skilled occupations, rather than a tendency for occupations to be filled with more skilled employees. It is not that, over time, a given task is performed by more skilled workers. Instead, employment is shifted from manual to non-manual stages of the production process.

Krueger (1993) found empirical support for wages being positively influenced by computer use. U.S. workers are rewarded a higher wage when using a computer to perform their job. The rise in the return to education is to a large degree caused by computer use. Unfortunately, Krueger does not account for the possibility of endogeneity in his estimates: Employees with higher skills or other individual charac-

³ This survey does not cover most of the literature under the heading "trade and wages", as the OECD (1997) has already put together such a survey. There is also a large body of literature that investigates the effects of technical change on the employment of a homogeneous factor labor (e.g. van Reenen 1964 and Katsoulacos 1986). The empirical evidence is mixed. The literature on SBTC reveals why this is not surprising: technical change affects different groups of workers in a different way.

teristics may be provided with a computer to perform their job more often than others. Thus, although Kruegers results clearly show that technical change has an impact on wages, it cannot be taken as water-proof evidence for the SBTC hypothesis.

Table 1 – Literature Survey of the Skill-Composition Debate

Authors, Year	Countries / Industries / Database / Period	Central Findings
Bound and Johnson (1992)	United States / manufacturing and some service sectors / Current Population Survey / 1973–88	SBTC drives labor demand.
Katz and Murphy (1992)	United States / all industries / Current Population Survey / 1963–87	SBTC rather than trade drives labor demand.
Krueger (1993)	United States / all industries / Current Population Survey and High School and Beyond Survey / 1984–89	Computer use is associated with 10–15 percent higher pay.
Berndt, Morrison, and Rosenblum (1992)	United States / manufacturing / Bureau of Economic Analysis data / 1952–86	Increasing high-tech composition of capital leads to skill-upgrading and higher white-collar employment.
Berman, Bound, and Griliches (1994)	United States / manufacturing / Annual Survey of Manufactures, Census of Manufactures, NBER trade data / 1959–87	Sectoral structural change accounts for less than one third of the shift from production to non-production workers.
Machin (1995)	United Kingdom / manufacturing / industry-level panel data set, Workplace Industrial Relations Surveys / 1979–90	SBTC rather than sectoral structural change drives labor demand. The effect of SBTC is more pronounced in R&D intensive industries.
Goldin and Katz (1996)	United States / manufacturing / U.S. census of manufactures / 1909–40	Evidence of a capital-skill complementarity.
Haskel (1996)	United Kingdom / manufacturing / New Earnings Survey Panel Data Set, Census of Production, Workplace Industrial Relations Survey, Customs and Excise data / 1980–89	Between industry changes account for little of the change in the skill-composition. Computer use has a significant influence on the skill-composition, while the influence of trade is negligible.

Table 1 continued

Authors, Year	Countries / Industries / Database / Period	Central Findings
Machin, Ryan, and van Reenan (1996)	United States, United Kingdom, Denmark, Sweden / manufacturing / STAN, United Nations database, Current Population Survey, Labour Force Survey / 1973-89	The change in the skill-composition occurs mainly within industries. A technology variable can account for around 24 percent of the change in the skill-composition.
Autor, Katz, and Krueger (1997)	United States / all industries / Census Public Use Micro Samples, Current Population Survey, National Income and Product Account, NBER Productivity Database / 1960-95	The change in the skill-composition occurs mainly within industries. Computer use is partly driving this development.
Berman, Bound, and Machin (1997)	OECD / manufacturing / United Nations General Industrial Statistics Database / 1980-90	Evidence for SBTC as the major driving force of labor demand is found across the country sample.
Bernard and Jensen (1997)	United States / manufacturing / Annual Survey of Manufactures / 1976-87	Shift-share analysis across industries finds support for SBTC. Shift-share analysis across plants finds support for SBTC and trade.
Blechinger and Pfeiffer (1997 and 1998)	West-Germany / manufacturing / Mannheim Innovation Panel / 1993-96	Positive relationship between innovative activity and the skill-share.
Doms, Dunne, and Troske (1997)	United States / manufacturing / Survey of Manufacturing Technology, Worker-Establishment Characteristic Database, Longitudinal Research Database / 1988-93	Cross-sectional analysis finds high tech plants employment more skilled workers. Time-series analysis finds no evidence of an increase in the skill-share after an innovation.
Falk and Koebel (1997)	Germany / all industries / Beschäftigtenstatistik, Lohn- und Gehaltsstatistik / 1977-94	SBTC drives labor demand.

Table 1 continued

Authors, Year	Countries / Industries / Database / Period	Central Findings
Garcia Cervero (1997)	United States / manufacturing / Annual Survey of Manufacturers / 1958-84	Industries with a higher rate of technical change have higher skill-share.
Kahn and Lim (1997)	United States / manufacturing / Current Population Survey, Annual Survey of Manufacturers / 1958-91	SBTC drives labor demand.
Licht et al. (1997)	Germany / service sector / ZEW service sector panel / 1995	Innovating firms have a higher than average skill-share.
Steiner and Wagner (1997)	West-Germany / manufacturing / IAB Beschäftigtenstichprobe / 1975-90	Both trade and SBTC explain only a small part of the change in the skill-composition.
Kearney (1998)	Ireland / manufacturing / panel data set by sector / 1979-90	SBTC is driving labor demand in high-growth sectors. Globalisation is driving labor demand in low-growth sectors. The medium-growth sectors remain stable.
Murphy, Riddell and Romer (1998)	United States, Canada / all industries / Current Population Survey, Survey of Consumer Finances, annual supplement to the Labour Force Survey / 1981-94	SBTC drives labor demand.

Berman, Bound, and Griliches (1994) look at the U.S. manufacturing sector to investigate whether it is trade or SBTC that drives the labor force's skill composition. They also find that between industry shifts, account for less than one third of the change in the skill composition. Most of the change is therefore explained by within industry changes, i.e. SBTC. Regressing, relative labor demand on use of computers and R&D spending among other standard explanatory variables lends support to their finding of SBTC. The authors concede themselves that their analysis should ideally also have considered the service sector, which was not included in their data. In fact, this shortcoming is unfortunate, since the service sector now employs a wide majority

of the labor force and produces a significant share of inputs for manufacturing (c.f. Klodt et al. 1997: p. 6 and 45). The sizeable employment shift between manufacturing and the service sector is not accounted for.

Machin, Ryan, and van Reenan (1996) find evidence for SBTC in the manufacturing sector of the United States, the United Kingdom, Denmark, and Sweden. Regression analysis shows a significant influence of computer use and R&D spending on the skill composition. However, these factors only explain part of the shift in relative labor demand. The authors identify union coverage, i.e. labor market institutions, as another important factor. For all four countries, union coverage reduces wage differentials by skill and slows down the shift towards a more skilled workforce. These results suggest to use a richer framework for the analysis of the skill composition, instead of merely including a technology indicator in a labor demand regression.

Autor, Katz and Krueger (1997) investigate the U.S. skill composition for a longer time period from 1940 to 1995, combining Census and CPS data. In their view of the data, SBTC in the form of computers is responsible for the acceleration of the shift of relative labor demand after 1970; they estimate that the spread of computer technology explains 30 to 50 percent of the acceleration. In their conclusions, the authors add a word of caution to their result (1997: p. 33):

„Although these conditional correlations of computer measures and the growth in the utilization of college workers and nonproduction workers may not reflect a causal relationship, it is clear that whatever is driving increases in the rate of growth of demand for skilled labor over the past twenty-five years is concentrated in the most computer-intensive sectors of the U.S. economy.“

The significant influence of computer use in regression analysis of the skill composition deserves critical reflection. A computer is a mechanical tool that is mostly used for routine tasks and processing

large information sets. The question then becomes whether computers are bought by firms and are then equipped with a skilled worker to operate them (technology push), or whether firms equip their skilled workers with computers to perform jobs in a more profitable way and at the same time expand these jobs because they become more important for profitability.

The findings of Doms, Dunne, and Troske (1997) shed some doubt on the SBTC hypothesis. In a cross-sectional analysis of the U.S. manufacturing sector, they find technologically advanced plants employing more educated workers and having a higher share of more skilled occupations, lending support for SBTC. However, in a time-series analysis, they find no evidence of a skill-intensification in the aftermath of the adoption of some new technology. In other words, while technologically advanced plants are more skill intensive, technical change does not lead them to increase their skill intensity further. This clearly speaks against the working of SBTC. Rather, a shift towards technologically more advanced plants appears to be hiding behind the residual SBTC. The results of Blechinger and Pfeiffer for Germany (1997, 1998) point in the same direction.

Bernard and Jensen (1997) analyze the effects of international trade and SBTC on the skill structure and the wage structure with plant level data for the U.S. manufacturing sector. Most of the change of the skill-composition is due to shifts towards exporting plants. However, technology variables are positively associated with the share of skilled labor at plant level. So while the SBTC hypothesis is not fully rejected, there are clearly other important forces at work.

While SBTC will play some role in explaining the changing skill composition, it is nothing more than a residual in empirical research.

As Gundlach and Nunnenkamp (1997: 7) argue, if it was actually technical change that worked in favor of skilled workers and against unskilled workers, we are faced with a break in the history of technical change. So far, technical change has always lifted all boats, even though it might have been biased towards the more skilled. For this to have changed, technical change must have slowed down significantly while being heavily biased in favor of the skilled.

4 A New View of the Structure of an Economy

The view of the structure of an economy suggested here looks at an economy in terms of the production process. It is therefore termed production process grid (PPG). The core of the process is the production of goods and services. Both of these branches use intermediate services as inputs. The three aspects of production are separated on the basis of industrial occupations. Thus, a single firm or even plant will consist of employees from several aspects. This would not be the case in a sectoral view, where establishments are assigned a sector according to their main economic activity. Therefore, the suggested PPG of the economy is at present able to describe only the employment structure, while the value-added structure cannot be described, unless the different aspects of the production process are grouped into separate profit centers within each firm. However, for analyzing the changing skill composition of the labor force, this will be sufficient.

4.1 Physical Production

Physical production is defined as the actual production of goods by labor assisted by a firm's capital stock. Hence, physical production takes place on the shop floor. It does not involve any executive decision-making, although the borderline might in some cases be vague.

Physical production requires knowledge of the tools and machinery used, and of the good being transformed. The required skill-level depends on the type of product (paper clips vs. microchips), the type of capital stock used in production (basic tools vs. computer), and whether a machine is assisted by human labor or whether human labor is assisted by a machine. In general, the more sophisticated a machine is and the more control a worker needs to exert over the machine, the higher the required skill-level will be. In the production process view of the economy, the implementation of more sophisticated machines constitutes SBTC.

One might think of subdividing physical production into low technology, medium technology, and high technology. Using this grid carries the danger of "defining away" SBTC. Moreover, some industries might change their character over time. The computer industry, for example, has its predecessor in the abacus industry. While the computer industry would count as high technology, the abacus industry would have counted as low or medium technology in its days.

To avoid such problems, physical production is subdivided into primary goods and secondary goods for the present analysis. Primary goods are the outputs of the agricultural sector, mining, energy, gas, and water. Secondary goods are the outputs of manufacturing sector, and construction. In both cases, only shop-floor workers are counted.

4.2 Personal Services

Personal services are those services that are consumed by individuals or households. These are the services that are thought to constitute the so called tertiary sector (cf. Fisher 1939, Clark 1940, Fourastié 1963). In particular, personal services are supplied by hotels and restaurants, schools and universities, hospitals and homes for the elderly, hair-dressers and dry-cleaners.

The skill requirements for personal services vary substantially with the type of service rendered. Therefore, they are subdivided into four branches: recreation, education, health, and other personal services, where education and health on average require a higher skill-level than recreation and the other personal services. Sectoral structural change as described by the three-sector hypothesis (*ibid.*) then does not have an unequivocal effect on the labor force's skill composition. It is important which personal service benefits most from sectoral structural change. Any within branch change of the skill-composition again reflects SBTC.

4.3 Intermediate Services

Intermediate services are those services that are used as an input to physical production or personal services, and to a lesser extent also for consumption. They consist of management and consulting, administration, retail and marketing, research and development, communication, financial services, and transport. The sectoral view of the economy adds most of these services to either physical production or personal services. This is unfortunate, as most employment dynamics is occurring in intermediate services. These services on average tend to have high skill requirements.

The fundamental change that drives much of the recent economic development and especially the skill composition is founded in the development of intermediate services. The production of goods has become more service intensive. Physical goods are embedded in a net of services, as customers are offered specific solutions to their problems instead of just a commodity. Intermediate services are separated from physical production through outsourcing and the formation of profit centers. Increased competition and the consumers' love of and for variety have forced firms to introduce more product differentiation, new management tools, and new organizational forms. The microelectronic revolution has provided the means for these strategies. In the terms of Johnson (1997) cited above, this would be labeled extensive technical change.

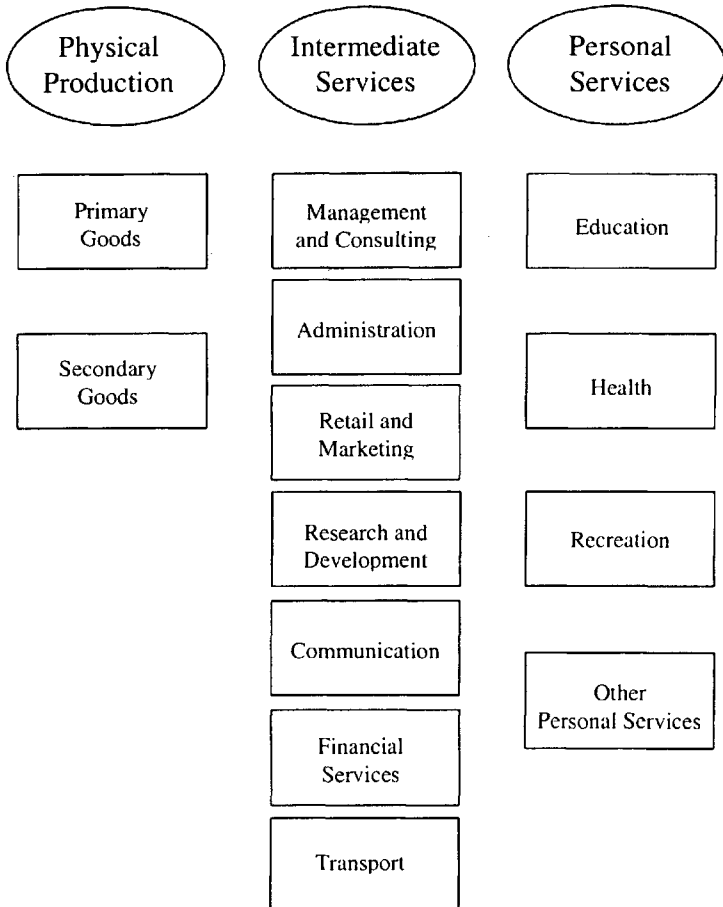
4.4 The Structure of the Economy

At the aggregate level, the economy is divided into the three branches outlined above: physical production, personal services, and intermediate services. These branches can be further subdivided (Figure 1). Physical production is subdivided into primary goods and secondary goods. Personal services are subdivided into education, health, recreation, and other personal services. Finally, intermediate services are subdivided into management and consulting, administration, retail and marketing, research and development, communication, financial services, and transport.

The result is a grid of several aspects of production that are all interrelated in some way. For example, management and consultancy services are provided for all other aspects. Health services are provided mostly for households, but can also be bought by firms for their staff in the form of a company doctor.⁴ Thus, if one was to do an input output analysis, all boxes of Figure 1 would have to be connected by arrows pointing both ways.

⁴ Table A1 shows how the PPG can be constructed from existing information about industrial sectors and industrial occupations.

Figure 1 – The Structure of the Economy



5 The Changing Skill Composition of the German Labor Force

5.1 The Data

The German Socio-economic Panel (GSOEP) is used to analyze whether the influence of SBTC is still dominant when the PPG is applied to an economy.⁵ The GSOEP is a household panel survey that has been conducted on an annual basis since 1984. The most recent data is available for 1996. It contains information on an individuals employment among other things. In particular, the GSOEP contains information about the formal qualification of an individual, the industry of her employment, and her occupation.

The skill composition is generated from the information on formal education.⁶ An individual is defined as unskilled, if she has no formal qualification, a primary school education, or a completed apprenticeship. An individual is defined as skilled, if she has advanced occupational training or a university degree. Table A2 shows this classification in more detail by using the German terminology.

The sectoral composition is generated from the information on an individuals industry of employment. The GSOEP industry classification, which corresponds with official standard classifications, is transformed into an 10 sector classification: agriculture, forestry and fishing; energy and water; mining; manufacturing; construction; wholesale and retail trade; transport and communication; financial services; other services; state, private households, non-profit organizations. It would have been preferable to split up manufacturing further. However, due to sample size limitations this was not feasible.

⁵ For a detailed description of the GSOEP see Haisken-De New and Frick (1997).

⁶ Formal education is one possibility to define skills (cf. Berman et al. 1994: 371).

Table A3 shows how the GSOEP classification is transformed into this reduced classification.

The PPG composition according to Figure 1 is generated from the information on an individual's occupation. The GSOEP uses the International Standard Classification of Occupations (ISCO) from 1973. Table A4 shows how the PPG is generated from the 2-digit ISCO.

The analysis is confined to the geographic region of West-Germany, so that data from before and after unification in 1990 are comparable. Individuals living in this geographic area can either be West-Germans, foreigners, or former East-Germans. To account for different sampling probabilities and to ensure that the results are representative for West-Germany, weights from the GSOEP are used for all calculations (cf. Frick and Haisken-De new 1997). Full-time and part-time employees as well as the self-employed are considered. Assuming that part-time employees work half the hours of a full-time employee on average, their weight is multiplied by 0.5.

5.2 Changes in the Skill Composition

Based on the GSOEP, the changes in the West-German skill composition are shown both from the sectoral view and the PPG. The small size of the GSOEP warrants some caveats in interpreting the data: The estimated sectoral and skill shares vary from year to year around a trend in a random fashion. It is therefore difficult to interpret annual changes. In particular, results can be sensitive to start and end values. To overcome this caveat, the start and end values are taken as the average of the first three years and the last three years of the GSOEP respectively. This eliminates some of the random variation in the data.⁷ Annual growth rates are computed as the coefficient of a regression of the log shares on a linear trend over the whole sample period.

⁷ The results are not sensitive with respect to setting the start and end periods to three years instead of two or four years.

From 1984 to 1996, the skill composition in the West-German economy has shifted towards the skilled (Table 2).⁸ The skilled share has risen from 40 percent of the employed in 1984/86 to 47 percent of the employed in 1994/96. This translates into an average growth rate of the skilled share in the total economy of 1.4 percent per year.

Defining a skill-intensive sector as having a skilled share above the economy average, Table 2 can be used to infer evidence for the SBTC hypothesis. Of the skill-intensive sectors in 1984/86, only the sector share of other services grew at a high, positive rate, implying that most of the skill-intensification must have taken place within sectors.

The picture changes when looking at the PPG of the West-German economy (Table 3).⁹ Five skill-intensive cells grew at an annual rate above one percent; they constitute 26 percent of employment. Of these, three cells grew at an annual rate above two percent; they constitute 14 percent of employment. Hence the PPG offers more evidence for the working of structural change than the sectoral view of an economy.

⁸ The sector shares as documented in Table 2 have been compared to sector shares computed from official figures taken from Sachverständigenrat (1997). As far as the sectors were comparable, the estimated shares from the GSOEP remained within a band of around one percentage point around the official shares.

⁹ Differences to the sectoral view in the figures for the total economy are due to a slightly different sample. The sectoral view and the PPG are derived from different variables in the GSOEP. Some individuals have not answered both of the underlying questions. In order to keep the sample as big as possible, I chose not to restrict the sample to those individuals who answered both questions.

Table 2 – Changes in the Skill Composition By Sector

	Sector Share			Skilled Share in Sector			Unskilled Share in Sector
	1984/86 ^a	1994/96 ^a	Growth Rate 84-96 ^b	1984/86 ^a	1994/96 ^a	Growth Rate 84-96 ^b	Growth Rate 84-96 ^b
Agriculture, forestry, fishing	3.83	2.98	-2.77	28.44	38.76	3.08	-1.54
Energy, water	2.01	2.20	1.06	48.65*	49.26*	0.12	-0.13
Mining	0.62	0.21	-9.90	26.46	58.00*	8.83	-5.52
Manufacturing	33.60	29.60	-1.28	31.53	39.26	2.05	-1.10
Construction	8.57	7.35	-1.56	33.04	34.99	0.52	-0.30
Wholesale and retail trade	10.23	11.92	1.96	24.73	31.01	2.17	-0.85
Transport, communication	5.99	6.14	0.29	42.34*	42.57	0.25	-0.20
Financial services	4.11	4.95	1.77	37.74	45.50	1.93	-1.36
Other services	17.58	22.36	2.30	59.66*	64.14*	0.66	-1.08
State, private households, non-profit organizations	13.48	12.30	-0.99	55.39*	59.07*	0.42	-0.60
Total Economy	100.00	100.00	—	40.19	46.73	1.40	-1.07

^aAverage share over three years. ^bGrowth rate in percent per year. Computed as the regression coefficient of the log share on a linear trend. —*Skill-intensive sector, defined as having a skill-share above the economy average.

Source: GSOEP (1997); own calculations.

Table 3 – Changes in the Skill Composition in the PPG

	PPG Share			Skilled Share in PPG			Unskilled Share in PPG
	1984/86 ^a	1994/96 ^a	Growth Rate 84–96 ^b	1984/86 ^a	1994/96 ^a	Growth Rate 84–96 ^b	Growth Rate 84–96 ^b
Primary Goods	4.96	3.03	-4.29	24.76	40.09	4.76	-2.24
Secondary Goods	30.11	26.43	-0.36	25.59	28.68	1.19	-0.44
Management & Consulting	4.52	7.57	5.92	55.25*	60.76*	0.98	-1.35
Administration	10.29	9.38	-0.19	46.47*	48.71*	0.42	-0.40
Retail and Marketing	8.12	7.61	-0.14	32.61	33.28	0.39	-0.18
Research & Development	5.46	6.43	2.35	81.40*	83.16*	0.13	-0.62
Communication	2.58	2.70	1.30	49.93*	51.53*	0.03	0.01
Financial Services	4.76	6.03	3.12	35.67	44.43	2.05	-1.35
Transport	5.84	5.97	1.03	23.38	23.60	0.16	-0.05
Education	4.81	5.01	0.93	98.25*	90.69*	-0.41	10.62
Health	4.02	5.71	4.14	71.07*	80.16*	1.10	-3.44
Recreation	5.14	4.33	-1.13	34.54	43.35	2.03	-1.37
Other Personal Services	9.38	9.81	1.52	48.47*	50.27*	0.06	-0.09
Total Economy	100.00	100.00	—	41.55	47.24	1.23	-0.98

^aAverage share over three years. ^bGrowth rate in percent per year. Computed as the regression coefficient of the log share on a linear trend. * Skill-intensive cell, defined as having a skill-share above the economy average.

Source: GSOEP (1997); own calculations.

5.3 Shift-Share Analysis

To test the SBTC hypothesis versus the structural change hypothesis more rigidly, a shift-share analysis can be used. The change in the skilled share in the economy ΔS_S is decomposed into two components according to equation (9).¹⁰ The first sum is the within-component. It captures the part that is due to changes in the skilled share within every sector $\Delta S_{S,i}$ for constant sector shares \bar{S}_i . The second sum is the between-component. It captures the part that is due to changes in the sector shares ΔS_i for constant skilled shares in the sectors $\bar{S}_{S,i}$.

$$\Delta S_S = \sum_{i=1}^n \Delta S_{S,i} \bar{S}_i + \sum_{i=1}^n \bar{S}_{S,i} \Delta S_i \quad (9)$$

The SBTC hypothesis implies that most of the change in the skilled share occurs within sectors, while the structural change hypothesis implies that most of the change in the skilled share occurs between sectors. Table 4 presents the results from the shift-share analysis both for the sectoral view and the PPG.

For the sectoral view, the between-component accounts for 15 percent of the change in the overall skilled share. Hence, the within-component accounts for the remaining 85 percent. These results are strong support for the SBTC hypothesis. The between-component is even smaller than the 30 percent found in other studies. This is due to the relatively high sectoral aggregation that had to be used in this study, because of the small sample size of the GSOEP. Disaggregating the economy further would have lead to insufficient numbers of observations per sector.

¹⁰ See Appendix 2 for a derivation of equation (9).

Applying the shift-share analysis to the PPG does not reverse the results completely.¹¹ However, the influence of the within component is reduced from 85 percent in the sectoral view to 59 percent in the PPG. Accordingly, the influence of the between-component rises from 15 percent in the sectoral view to 40 percent in the PPG.¹² Hence, structural change plays a more important role for the change in the skilled share when the economy is structured according to the PPG.¹³

Table 4 – Shift-Share Analysis: Change in the Skilled Share
1984/86 – 1994/96^a

	Total (percentage points) ^b	Between- Component (percentage points) ^b	Share of Total (percent) ^b	Within- Component (percentage points) ^b	Share of Total (percent) ^b
Sectoral View	6.53	1.01	15.43	5.55	84.94
PPG	5.69	2.30	40.44	3.36	59.00

^aStart and end values are the mean of the first and last three years respectively. The constant shares are the mean over the whole sample period. –^bFigures do not add up, because the shift-share decomposition contains a third interaction-component that cannot be computed from the data.

Source: GSOEP (1997); own calculations.

The working of structural change implied by the sectoral view differs from the working of structural change implied by the PPG. Structural change occurs because of demand-side changes, e.g. due to trade, or

¹¹ Again the total change differs between the sectoral view and the PPG due to slightly different samples.

¹² Figures do not add up, because the shift-share decomposition according to equation (9) should actually contain a third interaction-component that cannot be computed from the data.

¹³ These results are not sensitive with respect to the time span used for the start and end values.

because of different productivity growth across sectors. In the sectoral view, structural change leads to a reallocation of economic activity between the different sectors. In the PPG, structural change leads to a fundamental change in the production process that shifts economic activity from physical production to service activities around this physical production. This change will – to some extent – transcend sectors and individual firms. To a large part, however, it will occur within an individual sector or firm.

6 Summary

Across the OECD, the composition of the employed has shifted towards the skilled. In the empirical literature, this stylized fact is explained by a technical change that is skill-biased. Assuming unskilled and skilled labor to be the only production factors, a technical change is skill-biased if it leads to a fall in the wage share of the unskilled after controlling for changes in skill-composition of labor supply. Taking SBTC as an explanation for the changing skill-composition is unsatisfactory, because this technical change is merely a residual instead of an exogenous factor that can be filled with more meaning.

The existing literature already provides several clues as to the underlying factors behind SBTC: Existing jobs are augmented with more capital, especially in the form of office and communication technology that require skilled workers. This was termed intensive technical change. Moreover, new jobs are created that require more skilled workers than the ones they replace. This was termed extensive technical change. All of this takes place in the course of a fundamental change in the production process. Physical production is automatized and the physical product is surrounded by more and more service activities from R&D and marketing to customizing and selling solutions instead of mere physical products.

A view of the economy has been suggested to augment the traditional sectoral view. The PPG structures the economy in terms of the

production process. At an aggregate level, the economy is divided into physical production, personal services, and intermediate services. A shift-share analysis has been applied to data for West-Germany based on the GSOEP to test whether SBTC was still the dominant force when the economy is structured according to the PPG. While in the sectoral view structural change accounted for only 15 percent of the change in the skilled share, it accounted for 40 percent in the PPG. This is taken as evidence for the hypothesis that the change in the skill-composition is actually driven by the fundamental restructuring of the production process.

The present analysis should be extended in several ways. First, the GSOEP is a relatively small sample that does not allow for a deeper disaggregation of the data in both the sectoral view and the PPG. Also, the GSOEP covers only the time from 1984 to 1996, while the change in the skill-composition has started in the late seventies. Therefore, a better database is needed that might provide further insights. Second, the hypothesis of a fundamental restructuring of the production process needs to be formalized to make the argument more rigid. This should lead to a set of hypothesis to be tested empirically.

Such an extension of the present analysis should answer the question as to whether the present situation constitutes a long-run equilibrium or whether it constitutes a period of adjustment. The first position was already taken by Ricardo in (1821): "The opinion entertained by the laboring class that the employment of machinery is frequently detrimental to their interests is not founded upon prejudice and error, but is conformable to the correct principles of political economy." Schumpeter (1926) is a proponent of the second position: Labor will adjust to the necessities raised by technical change. In this setting, the answer to the question of whether it is SBTC or structural change that drives labor demand will provide insights as to how labor supply needs to adjust. SBTC or intensive technical change requires higher skills for existing occupations. Structural change or extensive technical change requires new skills for new occupations.

Table A1 – Merging the Sectoral and the Occupational View into the Production Process Grid

Sectoral View	Primary Sector Agriculture, Forestry, Fishing	Goods Producing Sector				Services				State	Private Households, Non-Profit Org.
		Electricity, Gas, Water	Mining	Manufacturing	Construction	Wholesale and Retail Trade	Communication, Transport	Financial Services	Other Services		
Occupational View											
Primary Activities	PP1										
Electricity, Gas, Water		PP1									
Mining			PP1								
Manufacturing				PP1							
Construction					PP1						
Recreation	PS1								PS1	PS1	PS1
Health	PS3	PS3	PS3	PS3	PS3	PS3	PS3	PS3	PS3	PS3	PS3
Education		PS2	PS2	PS2	PS2	PS2	PS2	PS2	PS2	PS2	PS2
										IS1	IS1
										IS2	IS2

Table A1 continued

Sectoral View	Primary Sector Agri- culture, Forestry, Fishing	Goods Producing Sector				Services				State	Private House- holds, Non- Profit Org.
		Elec- tricity, Gas, Water	Mining	Manu- fac- turing	Con- struc- tion	Whole- sale and Retail Trade	Com- muni- cation, Trans- port	Finan- cial Services	Other Ser- vices		
Occu- pational View											
Other Personal Services									PS4		
Distribution	IS3	IS3	IS3	IS3	IS3	IS3 IS1 IS2	IS3	IS3		IS3 IS1 IS2	
Transport	IS7	IS7	IS7	IS7	IS7	IS7 IS1 IS2	IS7 IS1 IS2		IS7	IS7	
Communi- cation	IS5	IS5	IS5	IS5	IS5	IS5	IS5 IS1 IS2	IS5	IS5	IS5	IS5
Financial Services	IS6	IS6	IS6	IS6	IS6	IS6	IS6	IS6 IS1 IS2	IS6	IS6	IS6

Table A1 continued

Sectoral View	Primary Sector Agriculture, Forestry, Fishing	Goods Producing Sector				Services				State	
		Electricity, Gas, Water	Mining	Manufacturing	Construction	Wholesale and Retail Trade	Communication, Transport	Financial Services	Other Services		
Occupational View											
Management, Consulting	IS1	IS1	IS1	IS1	IS1	IS1	IS1	IS1	IS1	IS1	IS1
Other Production Related Services	IS2 IS4	IS2 IS4	IS2 IS4	IS2 IS4	IS2 IS4	IS2 IS4	IS2 IS4	IS2 IS4	IS2 IS4	IS2 IS4	IS2 IS4
State											
Private Households, Non-Profit Org.											
Physical Production: PP1: Primary Goods; PP2: Secondary Goods. Intermediate Services: IS1: Management and Consulting; IS2: Administration; IS3: Retail and Marketing; IS4: Research and Development; IS5: Communication; IS6: Financial Services; IS7: Transport. Personal Services: PS1: Recreation; PS2: Education; PS3: Health; PS4: Other Personal Services.											

Table A2 – Definition of the Skill Variable

Skill Category	Degree	British / U.S. Equivalent
Unskilled	Kein Schulabschluß / kein Berufsabschluß	No degree at all
	Hauptschule	9 years of schooling
	Realschule	10 years of schooling
	Lehre	Apprenticeship
	Foreign primary school degree	
	Some on-the-job training	
Skilled	Abitur, weiterführende Schule im Ausland	University entrance certificate
	Berufsfachschule, Schule des Gesundheitswesens, Fachschule, Beamtenausbildung, berufsbildende Schule im Ausland	Advanced professional training
	Universität, Technische Hochschule, Fachhochschule	University degree

Table A3 – Defining the Sectoral Structure of an Economy from the GSOEP

Industrial Classification in the GSOEP	Sector Classification
Agriculture and Forestry	Agriculture, forestry, and fishing
Fishing industry	Agriculture, forestry, and fishing
Energy and water	Energy and water
Mining	Mining
Chemical industry	Manufacturing
Synthetic industry	Manufacturing
Clay, stone and earth	Manufacturing
Iron and steel industry	Manufacturing
Mechanical engineering	Manufacturing
Electrical engineering	Manufacturing
Wood, paper, printing	Manufacturing
Textile and clothing	Manufacturing
Food industry	Manufacturing
Construction	Construction
Construction related industries	Construction
Wholesale trade	Wholesale and retail trade
Trading agents	Wholesale and retail trade
Retail trade	Wholesale and retail trade
Train system	Transportation and communication
Postal system	Transportation and communication

Table A3 continued

Industrial Classification in the GSOEP	Sector Classification
Other traffic system	Transportation and communication
Financial institutions	Financial services
Insurance cocompanies	Financial services
Restaurants and inns	Other services
Service industry	Other services
Trash removal	Other services
Education, science and sports	Other services
Health service	Other services
Legal service	Other services
Other service	Other services
Non-profit group	State, private households, non-profit organisations
Private households	State, private households, non-profit organisations
Regional authority	State, private households, non-profit organisations
Social security	State, private households, non-profit organisations

Table A4 – Defining the Production Process Grid of an Economy from the GSOEP

Description	1-Digit ISCO	2-Digit ISCO	3-Digit ISCO	Production Process Grid
Professional, technical and related workers	1			
Physical scientists and related technicians		01		IS4
Architects, engineers and related technicians		02 and 03		IS4
Mining technicians			038	PP1
Aircraft and ship's officers		04		IS7
Life scientists and related technicians		05		IS4
Medical, dental, veterinary and related workers		06 and 07		PS2
Statisticians, mathematicians, systems analysts and related technicians		08		IS4
Systems analysts			083	IS5
Statistical and mathematical technicians			084	IS5
Economists		09		IS4
Accountants		11		IS1
Jurists		12		PS4
Teachers		13		PS1
Workers in religion		14		PS4
Authors, Journalists and related writers		15		PS3
Sculptors, painters, photographers and related creative artists		16		PS3
Commercial artists and designers			162	IS3
Composers and performing artists		17		PS3
Athletes, sportsmen and related workers		18		PS3
Librarians, archivists and curators			191	PS3

Table A4 continued

Description	1-Digit ISCO	2-Digit ISCO	3-Digit ISCO	Production Process Grid
Sociologists, anthropologists, related scientists			192	IS4
Social workers			193	PS4
Personnel and occupational specialists			194	IS1
Philologists, translators and interpreters			195	IS5
Other professional, technical and related workers			199	IS1
Administrative and managerial workers	2			IS1
Clerical and related workers	3			
Clerical supervisors		30		IS1
Government executive officials		31		IS2
Stenographers, typists and card- and tape-punching machine operators		32		IS2
Bookkeepers, cashiers and related workers		33		IS6
Computing machine operators		34		IS2
Transport and communications supervisors		35		IS1
Transport conductors		36		IS7
Mail Distribution clerks		37		IS5
Telephone and telegraph operators		38		IS5
Clerical and related workers not elsewhere classified		39		IS2
Sales Workers	4			
Managers (wholesale and retail trade)		40		IS1
Working proprietors (wholesale and retail trade)		41		IS3
Sales supervisors and buyer		42		IS2
Sales supervisors			421	IS1

Table A4 continued

Description	1-Digit ISCO	2-Digit ISCO	3-Digit ISCO	Production Process Grid
Buyers			422	IS2
Technical salesmen, commercial travelers and manufacturers' agents		43		IS3
Insurance, real estate, securities and business services salesmen and auctioneers		44		IS6
Insurance, real estate and securities salesmen			441	IS6
Business services salesmen			442	IS1
Auctioneers			443	IS6
Salesmen, shop assistants and related workers		45		IS3
Sales workers not elsewhere classified		49		IS3
Service workers	5			
Managers (catering and lodging services)		50		IS1
Working proprietors (catering and lodging services)		51		PS3
Housekeeping and relates service supervisors		52		PS3
Cooks, waiters, bartenders and related workers		53		PS3
Maids and related housekeeping service workers not elsewhere classified		54		PS4
Building caretakers, charworkers, cleaners and related workers		55		PS4
Launderers, dry-cleaner and pressers		56		PS4
Hairdressers, barbers, beauticians and related workers		57		PS4

Table A4 continued

Description	1-Digit ISCO	2-Digit ISCO	3-Digit ISCO	Production Process Grid
Protective service workers		58		PS4
Service workers not elsewhere classified		59		
Guides			591	PS3
Undertakers and embalmers			592	PS4
Other service workers			599	PS4
Agricultural, animal husbandry and forestry workers, fishermen and hunters	6			
Farm managers and supervisors		60		IS1
Farmers		61		PP1
Agricultural and animal husbandry workers		62		PP1
Forestry workers		63		PP1
Fishermen, hunters and related workers		64		PP1
Production and related workers, transport equipment	7			
Production supervisors and general foremen		70		PP2
Miners, quarrymen, well drillers and related workers		71		PP1
Metal processers		72		PP2
Wood Preparation workers and paper makers		73		PP2
Chemical Processers and related workers		74		PP2
Spinners, weavers, knitters, dyers and related workers		75		PP2
Tanners, fellmongers and pelt dressers		76		PP2
Food and beverage processers		77		PP2
Tobacco preparers and tobacco product makers		78		PP2

Table A4 continued

Description	1-Digit ISCO	2-Digit ISCO	3-Digit ISCO	Production Process Grid
Tailors, dressmakers, sewers, upholsterers and related workers		79		PP2
Shoemakers and leather goods makers		80		PP2
Cabinetmakers and related workers		81		PP2
Stone cutters and carvers		82		PP2
blacksmiths, toolmakers and machine-tool operators		83		PP2
Machinery fitters, machine as- semblers and precision instru- ment makers (except electrical)		84		PP2
Electrical fitters and related electrical and electronics workers		85		PP2
Broadcasting station and sound equipment operators and cinema projectionists		86		IS5
Plumbers, welders, sheet metal and structural metal preparers and erectors		87		PP2
Jewelry and precious metal workers		88		PP2
Glass formers, potters and related workers		89		PP2
Rubber and plastic product makers		90		PP2
Paper and paperboard products makers		91		PP2
Printers and related workers		92		PP2
Painters		93		PP2
Production and related workers not elsewhere classified		94		PP2

Table A4 continued

Description	1-Digit ISCO	2-Digit ISCO	3-Digit ISCO	Production Process Grid
Bricklayers, carpenters and other construction workers		95		PP2
Stationary engine and related equipment operators		96		PP1
Power-generating machinery operators			961	PP1
Stationary engine and related equipment operators not elsewhere classified			969	PP2
Material-handling and related equipment operators, dockers and freight handlers		97		PP2
Dockers and freight handlers			971	IS7
Riggers and cable splicers			972	PP2
Crane and hoist operators			973	PP2
Earth-moving and related machinery operators			974	PP2
Material-handling equipment operators not elsewhere classified			979	PP2
Transport equipment operators		98		IS7
Laborers not elsewhere classified		99		PP2
New workers seeking employment		101	001	PS4
Workers reporting occupations unidentifiable or inadequately described		102	002	PS4

Appendix 2 – Derivation of the Shift-Share Equation

Skilled employment E_S is the sum of skilled employment in all industries.

$$E_S = \sum_{i=1}^n E_{S,i} \quad (A1)$$

Skilled employment in industry i can be written as the product of the share of skilled employment in industry i $S_{S,i}$ and employment in industry i E_i .

$$E_S = \sum_{i=1}^n S_{S,i} E_i \quad (A2)$$

Employment in industry i can be written as the product of the share of employment in industry i S_i and total employment E .

$$E_S = \sum_{i=1}^n S_{S,i} S_i E \quad (A3)$$

Dividing through by E yields the share of skilled employment S_S .

$$S_S = \sum_{i=1}^n S_{S,i} S_i \quad (A4)$$

Discrete differentiation according to the product rule yields

$$\Delta S_S = \sum_{i=1}^n \Delta S_{S,i} \bar{S}_i + \sum_{i=1}^n \bar{S}_{S,i} \Delta S_i \quad (9)$$

The change in the employment share of skilled workers is thus decomposed into two major components.¹⁴ First, changes in the share of skilled workers within all industries for constant industry shares.

¹⁴ To be precise, there is a residual that results from the interaction of within-industry and between-industry changes.

Second, changes in the employment share of industries for constant skill shares within industries.

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