Changes in Returns to Multidimensional Skills across Cohorts*

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Abstract

While social skills grew important at work, other skills became less relevant. In Germany, between 1984 and 2020, the employment share of social task-intensive occupations grew by 18 percentage points, while it declined for those intensive in routine tasks. Relative to the existing literature, I account for unmeasured ability differences by using a dynamic model with endogenous skills, including cognitive, social and diligence skills. There is a positive change in returns to social skills, driven by high cognitive individuals. However, routine task displacement determines a negative change in returns to diligence skills for low cognitive individuals because of sorting into routine-intensive occupations.

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1 Introduction

Jobs are evolving due to technology, globalization, and educational expansion, among others. These factors are causing shifts in the demand and supply of skills, directly impacting labour market returns for skills. Yet, which skills are experiencing a rising (falling) demand and, as a result, yield higher (lower) returns over time?

The previous literature has focused on one single dimension of skills, proxied by educational attainment. Overall, the returns to skills have continued to grow over the last decades as "skill-biased" technology complements high-skilled workers while replacing low-skilled workers (Tinbergen, 1974, 1975; Levy et al., 1992; Goldin and Katz, 2008; Acemoglu and Autor, 2011). More recently, a growing literature has estimated changes in returns to multidimensional skills over time: social skills are increasingly rewarded because of a rising demand in occupations intensive in social tasks (Deming, 2017; Edin et al., 2022; Deming, 2023). However, while social skills grew important, other skills became less relevant (Castex and Kogan-Dechter, 2014; Ashworth et al., 2021). Three main points remain unaddressed. First, (i) the role of skills other than cognitive and social, such as diligence (Izadi and Tuhkuri, 2023). This difference is relevant, as declining occupations could value more other skills. Second, (ii) as in Deming (2017), there is a potential bias coming from unmeasured ability differences. Deming (2017) address this by controlling for years of completed education. However, (iii) years of completed education is endogenous to skills (Edin et al., 2022). This complicates the estimation of returns to skills as you can only estimate direct effects (Angrist and Pischke, 2009). Estimating total effects without accounting for unmeasured ability differences and sorting into college may produce a bias (Deming, 2017; Edin et al., 2022).

This paper addresses each of these points while identifying which skills are experiencing a rising (falling) demand, yielding higher (lower) returns over time. With respect to point (i), relative to Deming (2017) and Edin et al. (2020), I use one cognitive skill and two different non-cognitive skills: social and diligence skills. These are factors extracted using around 150 measures from the German Socio-Economic Panel Data (GSOEP) (Heckman et al., 2006; Cunha et al., 2010; Humphries et al., 2019; Ashworth et al., 2021; Toppeta, 2022). This includes standardized cognitive tests, GPA, parental involvement, advanced courses in secondary schooling, extracurricular activities, time allocation to activities, satisfaction, self-confidence, personality traits, risk and time preference, trust measures, locus of control, and other indicators such as the number of close friends (Humphries and Kosse, 2017). With respect to (ii) and (iii), I contribute substantially to the literature by providing a framework to estimate returns to multidimensional skills, accounting for skill endogeneity and exogenous unmeasured ability, using a dynamic model of joint educational choices, skill development, and labour market outcomes. Using this model solves the issues in Deming (2017) and Edin et al. (2022): it makes it possible to control for unmeasured ability differentials while estimating both direct and total effects, together with a rich set of heterogeneous treatment effects. Unobserved heterogeneity, i.e. exogenous ability, is identified using initial conditions, the panel structure of the data, local labour market conditions, and a set of exclusion restrictions, including school recommendations and reforms in Germany. To the best of my knowledge, this is one of the first papers to estimate the returns to endogenous skills, which can be modified by schooling or other interventions, while controlling for exogenous ability, which is, by definition, not modifiable. At last, I estimate a model of occupational sorting using multidimensional skills and the task content of occupations (Acemoglu and Autor, 2011). Moreover, skill demand in Germany between 1984 and 2020 is proxied using novel task measures using data from the European Skills, Competences, Qualifications and Occupations (ESCO). Unlike studies relying on a limited number of questions from employer surveys, i.e. O*NET, my approach incorporates an extensive list of thousands of objective task measures. Using a latent factor approach, I categorize the task content of occupations into routine, social, and non-routine analytical (cognitive) tasks, controlling for measurement error (Deming, 2017). ESCO is context-specific and readily applicable for cross-national analyses in Europe. This differs from papers, such as Edin et al. (2022) or Aghion et al. (2022), using O*NET for European countries.

I document significant changes in the task content of occupations and returns to multidimensional skills in Germany from 1984 to 2020. Using data from ESCO and GSOEP, there is evidence of the growing importance of social tasks and a decline in routine tasks. Non-routine analytical (cognitive) task content remained fairly stable, but the demand for cognitive tasks experienced a decline since the 2000s. Employment share surged by 18 percentage points for occupations emphasizing social skills, regardless of their cognitive task content. A rise (fall) in demand for specific tasks will increase (decrease) returns for individuals holding a comparative advantage, given their skills (Acemoglu and Autor, 2011). Using a novel dynamic model, I find a large and significant increase of 6.4 percentage points in the returns to social skills across cohorts. This is driven by higher complementarities between social and cognitive skills at the upper tail of the skill distribution. At the same time, there were no significant changes in the returns to cognitive skills. Most importantly, there is a negative change in returns to diligence skills. Low-cognitive individuals drive this result as they hold a comparative advantage in routine-intensive occupations. Moreover, these individuals do not experience a positive change in return to social skills. These trends align with the predictions of Acemoglu and Autor (2011) and are consistent with the growing importance of social skills in the labour market (Deming, 2017; Edin et al., 2022). Moreover, wage changes are closely connected to task displacement for a given group (Acemoglu and Restrepo, 2022): this paper shows that routine task displacement primarily harms low cognitive individuals, who were benefiting from high returns to diligence skills. At last, using a dynamic model allows me to analyze the development of multidimensional skills. I find that secondary education grade retention negatively impacts cognitive and diligence skills development without affecting social skills. In contrast, grade retention in primary education hurts all measures of skills, suggesting that social skills may follow a different development trajectory compared to cognitive and diligence skills.

Related Literature

My paper relates and contributes to various strands of the literature. First, it relates to the literature on changes in the labour market and the impact of technical change, globalization and other factors. One of the main components of this literature is represented by skill premium. Starting from the literature on skill-biased technical change (SBTC), rising skill premia are defined as a consequence of a "skill-biased" technology that complements skilled workers while substituting unskilled ones (Bound et al., 1992; Levy et al., 1992; Juhn et al., 1993; Goldin and Katz, 2008; Acemoglu and Autor, 2011). However, several papers have also documented a process of polarization, where employment and wages are growing at the ends of the skill distribution (Autor et al., 2003; Autor et al., 2006; Acemoglu and Autor, 2011; Autor and Handel, 2013; Goos et al., 2014; Bárány and Siegel, 2018; Acemoglu and Restrepo, 2022). This phenomenon has been observed in the US and Europe (Goos and Manning, 2007; Dustmann et al., 2009; Goos et al., 2009, 2014). This literature has usually proxied skill levels by educational attainment. This paper differs substantially as it considers the change in returns to multidimensional skills. Indeed, this paper relates to the growing literature that considers human capital to have multiple dimensions (Heckman et al., 2006; Heckman et al., 2018b; Humphries et al., 2019; Attanasio, Blundell, et al., 2020; Attanasio, Cattan, et al., 2020; Guvenen et al., 2020; Lise and Postel-Vinay, 2020; Toppeta, 2022; Deming, 2023; Izadi and Tuhkuri, 2023). Several papers have investigated the role of multidimensional skills, such as non-cognitive skills or personality traits, on labour market returns (Lindqvist and Vestman, 2011; Humphries and Kosse, 2017; Humphries et al., 2019; Todd and Zhang, 2020; Izadi and Tuhkuri, 2023). Others have provided evidence of changes in returns to multidimensional skills: there are lower returns to cognitive skills (Castex and Kogan-Dechter, 2014; Beaudry et al., 2016), and higher returns to social skills (Deming, 2017; Edin et al., 2022). My paper is closely connected to Deming (2017) and Edin et al. (2022). Deming (2017) estimates returns controlling for years of completed education, to account for a potential bias from unmeasured ability differentials. However, years of completed education is endogenous to skills and, therefore, it does not estimate total returns. This also happens in Edin et al. (2022), which estimates wage returns by holding educational attainment constant. I contribute substantially to the literature by providing a framework to estimate direct and total returns while controlling for unmeasured ability differences. My paper offers a new dynamic model of endogenous skills and exogenous abilities to estimate direct and total effects while considering a larger set of heterogeneous treatment effects. Using three dimensions of skills, I establish that, while social skills are growing, diligence skills are losing importance at work. This happens for low cognitive individuals as they are sorting into disappearing routine-intensive occupations.

Second, it relates to the literature using the so-called task-based approach. This approach has been refined in both employment polarization and changes in returns to multidimensional skills literature (Autor et al., 2003; Acemoglu and Autor, 2011; Deming, 2017; Edin et al., 2022). Focusing on the German context, Spitz-Oener (2006), Rohrbach-Schmidt and Tiemann (2013), and Koomen and Backes-Gellner (2022) have measured the task content of occupations. In my paper, I contribute to this literature by developing a new measure of task content using data from ESCO and employing a latent factor approach. This objective measure can be complemented with subjective measures used in previous studies, such as the BIBB/IAB and BIBB/BAuA Employment Surveys on Qualification and Working Conditions in Germany. Additionally, this measure could serve as an objective benchmark for European countries, facilitating cross-national comparisons.

Third, it relates to the literature on dynamic models of educational choices and labour market outcomes, starting from the seminal papers of Cameron and Heckman (1998, 2001). This paper uses a flexible dynamic discrete choice model developed by the dynamic treatment effects literature (Heckman and Navarro, 2007; Heckman et al., 2016, 2018a, 2018b; Ashworth et al., 2021). This approach has been applied by, among others, Colding et al. (2006), Belzil and Poinas (2010), Ashworth et al. (2021), De Groote (2022), Neyt et al. (2022), and Navarini and Verhaest (2023). A set of papers have introduced multidimensional skills in dynamic models (Humphries et al., 2019; Guvenen et al., 2020; Lise and Postel-Vinay, 2020) and estimated changes to returns across cohorts using a dynamic model (Ashworth et al., 2021). Ashworth et al. (2021) is a related paper, as it estimates a dynamic model for two cohorts while considering changes in returns to cognitive and non-cognitive skills. However, my paper differs substantially as it is the first to model skills as endogenous while accounting for unmeasured innate ability. At last, using a dynamic model, I can take a stance on the development of multidimensional skills (Cunha and Heckman, 2008; Cunha et al., 2010; Agostinelli and Wiswall, 2016; Heckman and Raut, 2016; Agostinelli et al., 2020; Sorrenti et al., 2020).

The rest of the paper is organised as follows. Section 2 introduces the data and describes the institutional context. Section 3 describes the model and the method to identify changes in returns to skill across cohorts. Section 4 includes the results of the model. Section 5 presents a series of robustness checks. At last, Section 6 concludes the paper.

2 Institutional Context and Data

This section describes the institutional context of Germany and introduces the data. I use two primary sources of data: ESCO and GSOEP. Further details about the data are discussed in Section A of the Appendix.

2.1 Institutional Context

In Germany, the compulsory education system covers the age range from 5 or 6 years old up to 18 years old. Primary school (*Grundschule*), which usually lasts for four years, provides a fundamental education in subjects such as mathematics, German, and science.[1] Students usually receive instruction in all main subjects from a single teacher during this stage. Upon completion of primary school, students move on to secondary school.[2] At this point, schools recommend a track based on students' grades and attitudes. Individuals may receive a lower, intermediate, or upper secondary schooling recommendation.[3] In some federal states, these recommendations are mandatory, meaning that students cannot easily transition to a different type of secondary school from the one recommended. However, in other states, families are not bound by these recommendations and have the freedom to choose the secondary school type. Over the last decades, federal states in Germany have substantially reformed school recommendations: several states have abolished binding recommendations to replace them with non-binding ones, and vice versa while other states have switched back and forth (Grewenig, 2022). At this stage, children are assigned to one of three distinct tracks: the lower (basic) track (*Hauptschulabschluss*), the intermediate track (*Realschulabschluss*), or the upper (academic) track, which extends until grade 13 (or 12) and leads to the university entrance qualification known as *Abitur*. The lower and intermediate tracks prepare students for vocational training or other practical forms of education. Therefore, different tracks have a potential effect on skill development, with certain tracks supporting the development of specific skills. While many school models now integrate lower and intermediate tracks, the upper track is primarily offered by *Gymnasium*, a school with an academic focus. Although it is possible to switch to higher-track schools, it is relatively uncommon. In 2000, only 1.5% of students switched to a higher track between grades 5 and 9 (Grewenig, 2022). After completing the lower or middle track, students typically enter a vocational training course, most commonly an apprenticeship. Apprenticeship training is often necessary for entry into specific skilled jobs. Moreover, two distinctive types of higher education institutions exist in Germany:

[1] Six years in Berlin and Brandenburg.

[2] Students may repeat a grade both in primary and secondary education. One-fifth of all students (20.3%) in Germany experience grade retention and repetition during their school career, and it is above the average rate in OECD countries (i.e., 12.4% of all students, OECD, 2013).

[3] Some individuals may not receive a recommendation, or I may not observe the recommendation of individuals in the dataset, see Appendix A.2.

universities for higher-level tertiary education and technical colleges (Fachhochschule) for lower-level.

2.2 Data

ESCO

Table 1: Top 10 ISCO-08 Occupations by Factor of Task Content

Social	Routine	Cognitive
1349-Professional services managers not elsewhere classified	3115-Mechanical engineering technicians	2149-Engineering professionals not elsewhere classified
2310-University and higher education teachers	3119-Physical and engineering science technicians not elsewhere classified	1349-Professional services managers not elsewhere classified
2431-Advertising and marketing professionals	3123-Construction supervisors	2141-Industrial and production engineers
3435-Other artistic and cultural associate professionals	2149-Engineering professionals not elsewhere classified	3119-Physical and engineering science technicians not elsewhere classified
2131-Biologists, botanists, zoologists and related professionals	3114-Electronics engineering technicians	3115-Mechanical engineering technicians
2269-Health professionals not elsewhere classified	8142-Plastic products machine operators	1324-Supply, distribution and related managers
2422-Policy administration professionals	7223-Metal working machine tool setters and operators	2152-Electronics engineers
1431-Sports, recreation and cultural centre managers	7213-Sheet-metal workers	2144-Mechanical engineers
2141-Industrial and production engineers	8219-Assemblers not elsewhere classified	2310-University and higher education teachers
1324-Supply, distribution and related managers	8212-Electrical and electronic equipment assemblers	1223-Research and development managers

Notes: I sort ISCO08 4 digits occupations by using the latent factors. This table includes the top 10 occupations sorted by each latent factors.

The ESCO is a dictionary of task content of occupation, developed by the European Commission. It contains information on 3,008 occupations (ISCO-08) based on 13,890 skill requirements and relative descriptions. These narrower skill descriptions are included in broader skill groups. I reduce the dimensionality of this data by extracting three factors. I interpret these factors as three measures of task content, following Deming (2017): routine, non-routine analytical (cognitive), and social tasks. Section A.1 in the Appendix includes a detailed description of the latent factors approach used and of alternative measures, used in Section D.1, as a robustness check. I link the resulting classification to the German Socio-Economic Panel (GSOEP), which includes panel data from 1984 to 2020 in Germany. Using ESCO and GSOEP together, I investigate the changes in the task content of occupations over this period. Table 1 includes a set of the top 10 ISCO-08 occupations sorted based on task content.[4]

[4]For instance, occupations intensive in social skills are, among others: "Policy administration professionals", "Sports, recreation and cultural centre managers", as well as "Advertising and marketing

GSOEP

The German Socio-Economic Panel (GSOEP) is a longitudinal micro-dataset in Germany, started in 1984. In this paper, I use the version of the data set that includes years up to 2020 (wave 37, SOEP, 2022). Beginning in 2000, a Youth questionnaire was administered to all young people at the age of 17, which contained specific questions about education and skills. The GSOEP includes a set of standardized tests for measuring cognitive skills and a set of measures of non-cognitive skills. The GSOEP's Youth Questionnaire contains data on 9,370 individuals, which can be complemented with subsequent individual questionnaires. Of the 9,370 individuals, data on potential cognitive performance is available for 4,055. These are individuals born between 1982 and 2003. A full description of how I construct my variables, including the factors measuring multidimensional skills, can be found in Section A.2 in the Appendix. I utilize data on cognitive and non-cognitive skills included in the GSOEP (see also Humphries and Kosse, 2017). Regarding cognitive skills, I use the data on standardized tests from the COGDJ questionnaire and information on secondary schooling GPA, advanced courses in secondary education, and parental involvement in school.[5] I use a large set of measures to identify two factors regarding non-cognitive skills. This allows the definition of two different factors: externalizing (social) and internalizing (diligence) skills (Toppeta, 2022). This list of measures is summarized in Table 2 (for more information on the latent factors and the detailed list of measures, see A.2.2 in the Appendix). I denote latent factors with θ: θ^c, θ^s, and θ^d denotes respectively cognitive, social, and diligence skills.[6] The latter measures discipline, conscientiousness, and internalized focus.[7] I study changes in returns across demographic cohorts and, therefore, I define two demographic cohorts: M, those born before 1995 (Millennials, following a definition of demographic cohorts), and Z, those born after 1995

professionals". Occupations with a high content of routine tasks are, for instance: "Metal working machine tool setters and operators" or "Mechanical engineering technicians". Last, occupations with high cognitive task content are: "University and higher education teachers", "Industrial and production engineers" and "Electronics engineers".

[5]COGDJ questionnaire includes standardized tests in verbal, numerical, and figural.

[6]Heckman et al. (2006) and Deming (2017) measure non-cognitive skills using a normalized average of the Rotter Locus of Control and the Rosenberg Self-Esteem scale. In this paper, I utilize a factor extracted from a large set of measures, including Locus of Control and a measure of Self-Esteem. The latter could be extracted from questions about the probability of future events.

[7]Table 20 in Appendix shows the correlation between these three factors and the 15 questions used for extracting the so-called Big 5 personality traits. As Table 20 shows, θ^d strongly correlates with the following personal characteristics: working carefully and carrying out duties efficiently. On the other side, it is negatively correlated with being lazy. These are the Big 5 questions associated with conscientiousness: individuals high in this trait have self-discipline, are diligent, and are organized and prepared.

(also known as Generation Z). See more details in Section A.2.1 in the Appendix.

Table 2: Measuerement System for Multidimensional Skills

Measures		θ^c	θ^{nc}	θ^{sc}
Cognitive tests (COGDJ)				
20 Analogies questions	b	x		
20 Arithemtic Operator questions	b	x		
20 Figures questions	b	x		
Youth Questionnaire (JUGENDL)				
GPA (German, Math, 1. Foreign language)	c	x		
Advanced Course (German, Math, 1. Foreign language)	b	x		
Support tutor	b	x		
Upper track preferred certificate	b	x		
Parents Show Interest In ... [7 questions]	b	x		
Involvement in school [11 questions]	b		x	x
How Often ... [12 questions]	c		x	x
Satisfaction With [4 questions]	c		x	x
Probability in %: .. [12 questions]	c		x	x
Willingness to take risks	c		x	x
Trust People [3 questions]	c		x	x
Have fun today, not think about tomorrow	c		x	x
Personal characteristics: work carefully	c		x	
Personal characteristics: communicative	c			x
Personal characteristics: ... [14 questions]	c		x	x
Frequency of Being ... [4 questions]	c		x	x
Political Interests	c		x	x
Locus of control [10 questions]	c		x	x
Amount Of Closed Friends	c		x	x

Notes: the second column includes a b for binary outcomes and a c for continuous ones. Measures in bold are used for identifying the latent factors (see more details in Section A in the Appendix). θ^c denotes a latent factor extracted using dedicated measures related to cognitive skills, while θ^{nc} and θ^{sc} are latent factors extracted by a set of measures related to non-cognitive skills, such as personal characteristics or locus of control. See details about latent factors and a detailed table with the full list of the measurement system in Section A.2.2 in the Appendix.

2.3 Exogenous Variables

Table 3 includes observed characteristics for individuals in the two demographic cohorts. There is a set of parental background characteristics to capture potential differences in parental early schooling investment: upper secondary schooling diploma, university degree, and high-skilled occupation. There are also geographical characteristics: whether she resides in a big or middle-sized city (relative to a small city or rural area) and if she resides in West Germany.

In Figure 1, I show the sorting and skill development patterns for individuals with different skills into secondary education tracks. Regarding θ^c, a clear pattern emerges. Those in the upper track exhibit higher cognitive skills than the mean. In contrast, the intermediate track aligns closely with the mean, while the lower track falls notably

Table 3: Exogenous Variables

	(1) M (1982-1995) mean	SD	(2) Z (1996-2003) mean	SD
Sex	0.495	0.500	0.497	0.500
Migration Background	0.227	0.419	0.334	0.472
Born in Germany	0.940	0.237	0.862	0.345
Siblings	1.622	1.339	1.467	1.534
Birth Year	1989.106	4.085	1999.409	2.254
Father Upper Secondary Education	0.195	0.396	0.180	0.384
Mother Upper Secondary Education	0.176	0.381	0.177	0.382
Father University	0.155	0.362	0.141	0.348
Mother University	0.106	0.308	0.115	0.319
Father High-Skilled Occupation	0.498	0.500	0.391	0.488
Mother High-Skilled Occupation	0.353	0.478	0.333	0.471
Big or middle-sized city	0.399	0.490	0.336	0.472
West Germany	0.793	0.405	0.838	0.369
Observations	4936		4432	

Notes: M denotes Millennials (born between 1982 and 1995), wile Z includes individuals born in Generation Z (born between 1995 and 2003). Father and Mother Education denotes the proprtion of parents holding an *Abitur*, with an upper secondary schooling completed. Father and Mother University denotes the portion of parents who completed a university degree. Father and Mother High-Skilled Occupation denotes individuals with a parent in a occupation classified as high-skilled in GSOEP. Big or middle-sized city is relative to the city of residence of the individual at the age of 17. This Table is produced using the full Youth questionnaire at disposal.

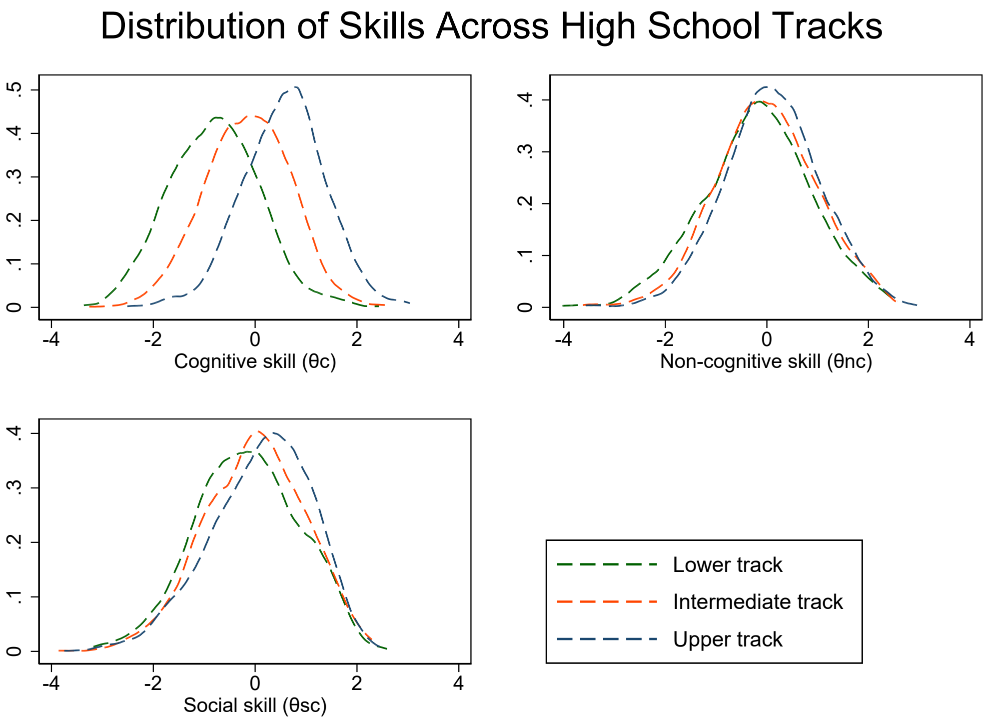


Figure 1: Distribution of Skills across High-School Tracks

Notes: details on the latent factors used in this Figure are included in A.2 in the Appendix. Latent factors θ are standardized to be mean 0 and standard deviation 1.

below the mean. This may result from high-cognitive individuals sorting in the upper track, while it may also be the result of a focus on cognitive skill development in upper tracks relative to other tracks. Regarding θ^d and θ^s, the sorting pattern aligns with the one observed for θ^c, but is less strong. Overall, individuals in the upper track show, on average, higher skills in all three multidimensional skills.

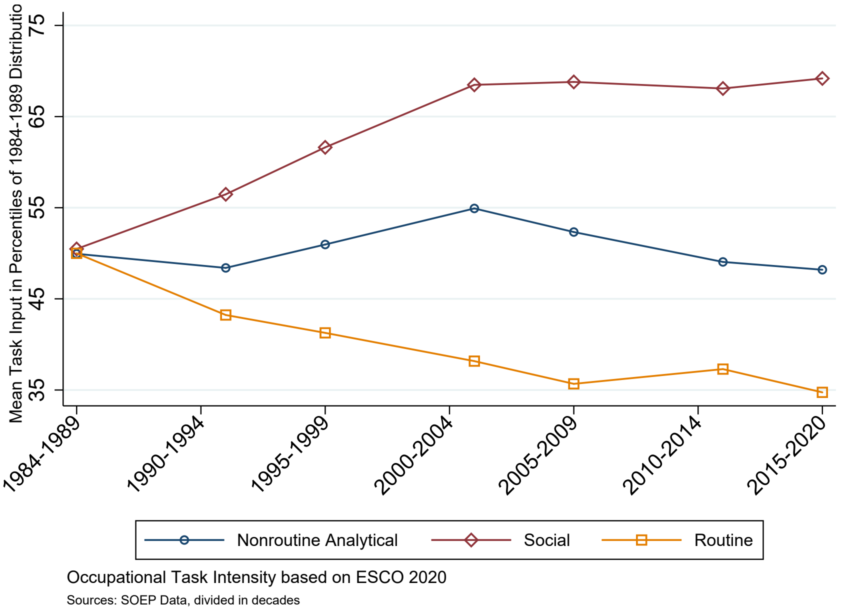
2.4 Changes in Tasks

Using data from ESCO and GSOEP, I estimate the changes in task content of occupation in Germany over the period from 1984 to 2020. Considering the panel data nature of the GSOEP, I select the last available observation for individuals in each half-decade from 1984 to 2020. This results in a single observation per individual for each half-decade. Following Deming (2017) closely, I ensure that each task measure variable has a mean of 50 centiles in 1984 and the data are aggregated to the industry-education-sex level. This controls for changes in the industry and labour supply in the German economy. Indeed, subsequent movements should be interpreted as changes in the employment-weighted mean of each task relative to its importance in 1984. Figure 2 replicates both Figure I from Autor et al. (2003) and Figure III from Deming (2017) using data from the GSOEP and the ESCO.

Overall, there has been a significant increase in social task-intensive occupations. I find that the labour input of routine tasks has declined over this period. Routine task input declined by a stark -30%, comparable to the results of Deming (2017) for the US economy. The decline in routine tasks essentially mirrors the growing importance of social tasks in the labour force between 1984 and 2020 in Germany. Moreover, I find that, despite an initial increase in the task content of non-routine analytical (cognitive) between 1984 and the early 2000s, after 2000 this has declined and it is now at a stable level relative to 1984. Overall, this is consistent with the sharp decline of non-routine analytical (cognitive) task measures observed by Beaudry et al. (2016) in the United States starting from the early 2000s. I control for possible skill upgrading by dividing occupations into four categories based on whether they are above or below the median percentile in both non-routine analytical (cognitive) and social skill task intensity (see also Deming, 2017).[8] I then compute the share of all labor supply-weighted employment in each category and year.

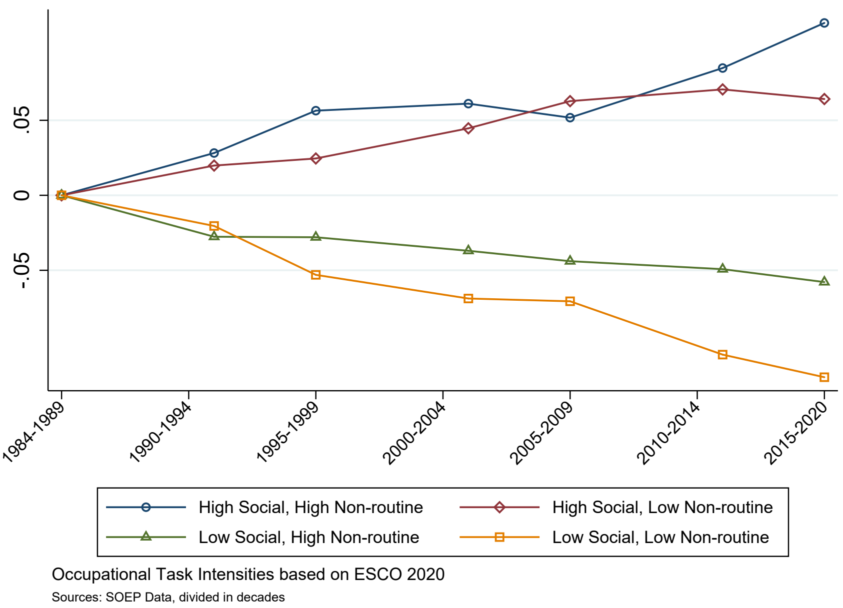
[8]In Deming, 2017, possible skill upgrading may be the result of the high correlation between social and non-routine analytical (cognitive) skills task measures.

Figure 2: Worker Tasks in Germany, 1984-2020



Notes: Figure 2 is constructed to parallel Figure I of Autor et al. (2003) and Figure III of Deming (2017), using data from Germany. Task measures are factors extracted by a large set of skill requirements and task descriptions by occupation (ESCO). See more details in Section B.2 in the Appendix. Data are aggregated to industry-education-sex cells by year, and each cell is assigned a value corresponding to its rank in the 1984 distribution of task input. Each task measure variable has a mean of 50 centiles in 1984. Plotted values depict the employment-weighted mean of each assigned percentile in the indicated year.

Figure 3: Relative Changes by Occupation Task Intensity (1984-2020)



Notes: Each line plots 100 times the change in employment share (relative to a 1984 baseline) between 1894 and 2020 for occupations that are above and/or below the 50th percentile in non-routine analytical and social skill task intensity as measured by ESCO for the German economy. Source: GSOEP Data and ESCO.

Figure 3 shows that the employment share of occupations intensive in social tasks, regardless of their non-routine analytical task content, has grown over the period by 18 percentage points. Also, there has been a large decline in the employment share of low social, low cognitive intensive occupations. This is especially important in our setting, as it shows that there is a strong change in the demand for social and cognitive tasks between the early 2000s and the post-2010, which is the main threshold between the two demographic cohorts in the analysis.

2.5 Tasks and Skills: Theoretical Framework

Using the model of Acemoglu and Autor (2011), it is possible to formulate hypotheses regarding the returns on skills by examining the observed patterns of changes in the task content. Notably, this model offers a stark prediction. Suppose the relative market price of tasks where a particular skill group hold a comparative advantage decreases. In that case, the relative wages of that skill group are expected to decline, regardless of whether the group reallocates its labour to a different set of tasks due to the shift in comparative advantage. In this setting, a rise (fall) in the skill demand will produce an increase (decline) in the relative market price.[9] Considering these three task measures, the relative market price of social tasks has increased over time, mirroring a large decline in the relative market price of routine tasks. As these tasks have become more (less) important in the labour force, there has been a greater (weaker) demand for individuals with a comparative advantage in performing these tasks. This generates increasing returns over time. Therefore, I expect (i) an increase in the returns to social skills, as also predicted by the model of Deming (2017). However, other multidimensional skills play a role too. As the demand for non-routine analytical skill task measures has remained rather stable over the last decades, (ii) I do not expect a significant change in the returns to cognitive skills. At last, (iii) I expect a decline in the returns to diligence skills, as individuals with high diligence skills may have a comparative advantage in performing routine tasks.

[9] Acemoglu and Autor (2011) consider a technological change that raises the productivity of high-skill workers in all tasks. The model's output is that high-skill workers would now perform some tasks formerly performed by middle-skilled workers. Relative wages paid to workers performing these (once) "middle-skill" tasks would increase since more productive high-skill workers now perform them. However, crucially, their analysis shows that the relative wages of medium-skill workers formerly performing these tasks would fall. In my paper, I do not consider measures of low to high-skilled workers, but I do consider workers with a bundle of multidimensional skills. The results are intuitively similar: e.g. individuals with high social skills have a comparative advantage in performing occupations intensive in social tasks.

This is conditional on both social and cognitive skills. As diligence skills, in my setting, are indicative of diligence, not being lazy, and conscientiousness, these hypotheses are in line with Heckman et al. (2006). Indeed, there is evidence that employers in low-skill labour markets value docility, dependability, and persistence more than cognitive ability or independent thought (Bowles and Gintis, 2002; Heckman et al., 2006). In this way, low-skilled and high-routine jobs may have strong wage returns to higher values of diligence skills.

3 Identifying Returns to Multidimensional Skills

Table 4: Preliminary Evidence: OLS Regression

	Starting log hourly wage		
	(1)	(2)	(3)
Cognitive skills θ^c	0.162***	0.0776***	0.0284
	(8.58)	(3.51)	(1.40)
- Change across cohorts	-0.0768*	0.00944	0.0466
	(-2.49)	(0.26)	(1.37)
Diligence skills θ^d	0.0628**	0.0531**	0.0197
	(3.22)	(2.74)	(1.08)
- Change across cohorts	-0.0644*	-0.0560	-0.0116
	(-1.98)	(-1.72)	(-0.41)
Social skills θ^s	0.0281	0.00285	-0.00200
	(1.49)	(0.15)	(-0.11)
- Change across cohorts	0.0234	0.0513	0.0278
	(0.72)	(1.57)	(0.88)
Cohort-specific individual characteristics	No	Yes	Yes
Cohort-specific educational choices	No	No	Yes

Notes: estimates of returns to multidimensional skills and changes across cohorts using OLS. All parameters are cohort-specific. Individual characteristics included exogenous variables, as included in Table 3. Educational choices include endogenous outcomes related to education: grade retention in primary and secondary education, high-school track diploma, higher tertiary education enrollment and diploma. Starting hourly wages are log wages for the first job of the individual. The sample is restricted to individuals with a wage, without including individuals who are not working. N is 2,219. t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In this section, I develop a novel model that is a flexible dynamic discrete choice model, as developed by the dynamic treatment effects literature, incorporating both endogenous skills and exogenous ability (Heckman and Navarro, 2007; Heckman et al., 2016, 2018a, 2018b; Ashworth et al., 2021). A dynamic model is essential to estimate causal returns to skills: Deming (2017) and Edin et al. (2022) estimate returns to multidimensional skills, controlling for educational attainment and years of completed education. This is done to account for a possible bias coming from unmeasured ability differences. However, it does not allow to compute both direct and total effects. In Table 4, I estimate returns to multidimensional skills and the relative changes across cohorts using a linear regression, while including cohort-specific individual characteristics and educational choices. I fail to find changes across cohorts. Moreover, when including educational choices, the returns to multidimensional skills are sensibly lower. This happens because post-measurement educational choices are not fixed at the time the regressors of interest, multidimensional skills, were determined (Angrist and Pischke, 2009). Using a dynamic model, I solve these issues, as I can estimate both direct and total returns, while accounting for unmeasured ability differences.

3.1 General Conceptual Framework

The GSOEP provides data on multidimensional skills for individuals aged 17. I refer to the period between primary education and age 17 as the schooling phase and the period between 17 and entry into the labor market as the school-to-work transition phase, as illustrated in Figure 4.

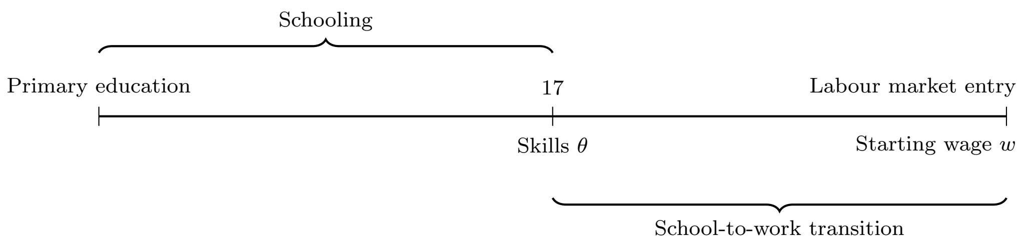


Figure 4: Timing

Skills θ are endogenous to schooling choices and individual characteristics. This underlines the potential impact of environmental factors on skill development. I assume that individuals differ in their innate ability and exists a number $m \in M$ of unobserved types. Individuals have m-specific functions of skill development, schooling and labour market outcomes. Therefore, a general function, as in Equation 1, could represent skills θ^j for $j \in J$, with J representing a set of multidimensional skills:

$$\theta_i^j = f_m^{\theta j}(X_i, f_m^s(X_i)), \tag{1}$$

where skills depend upon schooling choices, $f_m^s(X_i)$ and observed characteristics, X_i, including parental background. This perspective aligns with contemporary findings in epigenetics, which emphasize the combined influence of genetics and the environment in shaping certain traits (Heckman, 2008). Once realized at the age of 17, multidimensional skills affect both post-compulsory education choices (after the age of 17), including the last years of secondary education and tertiary education choices, together with labour market outcomes. Therefore, from a general perspective, starting wages log(wage) could be modeled as a function of individual characteristics, X_i, schooling choices, f_m^s, multidimensional skills, θ_i^j and post-compulsory educational choices, f_m^e:

$$\log(wage)_i = f_m^w\Bigg(X_i, f_m^s(X_i), \theta_i^j, f_m^e\Big(X_i, f_m^s(X_i), \theta_i^j\Big)\Bigg), \tag{2}$$

where (2) is a general version of my benchmark model: skills and post-compulsory educational choices are also functions of previous variables. In this dynamic setting, skills θ_i^j not only directly influence wages but also have indirect effects through educational outcomes.

3.2 Model

Each individual $i \in I$, a member of demographic cohort c, undergoes a process of dynamic human capital accumulation. Following Ashworth et al. (2021), the model is estimated separately for each demographic cohort c. For the sake of clarity, subscript c is suppressed in subsequent equations.[10]

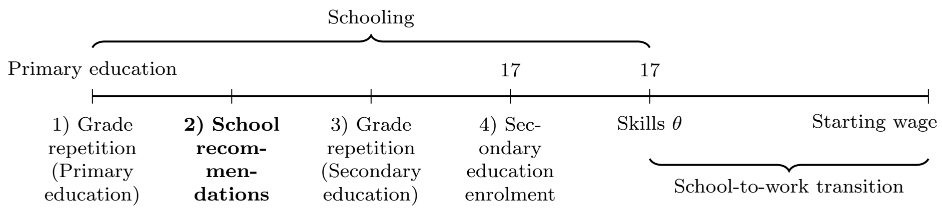


Figure 5: Model: Schooling Phase

I model choices from primary education to entry into the labour market. Let t denote the sequence of choices and outcomes in the model. Before skill measurement, there is a set of choices during the schooling phase, as shown in Figure 5. At $t = 1$, students repeat

[10]The model should always be interpreted as cohort c specific

a grade in primary education or not, $D_1(\kappa_1)$, where $\kappa_1 \in \mathcal{K}_1 = \{0, 1\}$, with $\kappa_1 = 1$ defining repeating a grade. This depends upon time-unvarying observed characteristics (X_i) and t-specific local labour market conditions (L_{it}). Beyond X_i and L_{it}, I account for initial heterogeneity by introducing an additional state m, unobserved and persistent over time. This allows for correlation across the choices and outcomes of the model, accounting for unobserved heterogeneity and dynamic selection while relaxing i.i.d. assumptions. I assume the existence of $m = 1, ..., M$ types that differ in their preferences, skill development process, as well as educational and labour market productivity. At the end of primary education, individuals receive a school recommendation from schools and their teachers ($D_2(\kappa_2)$), as described in Section 2.1. Let $\kappa_2 \in \mathcal{K}_2 = \{0, 1, 2, 3\}$ denote, respectively, no recommendation, lower, intermediate and upper secondary education recommendation. At $t = 3$, individuals may repeat a grade in secondary education before the age of 17 ($D_3(\kappa_3)$). Grade repetition has largely long-term adverse effects, with lower chances of graduating from high school and possible long-term effects on skill development (Cockx et al., 2019). Upon skill measurement, individuals choose which track to enrol in secondary schooling, $D_4(\kappa_4)$ with $\kappa_4 = \kappa_2 \in \mathcal{K}_2$. After secondary school enrolment, at the age of 17, $t = \{5, 6, 7\}$, I include a set of multidimensional endogenous skills θ_i^j with $j \in \{c, d, s\}$ denoting cognitive, diligence and social skills. At this point, multidimensional skills θ_i^j, as measured at the age of 17, impact the likelihood of obtaining a specific secondary education diploma (or the relative probability of dropping out), enrolment and completion of a tertiary education degree. Consequently, these choices directly impact starting wages, as Figure 6 describes. Each skill θ_i^j for $j \in \{c, s, d\}$ is endogenous into the dynamic model. These factors are estimated in a first stage, see further details in Section A.1.2 in the Appendix. Each skill θ is the result of a development process that starts as early as schooling. Moreover, local unemployment may influence skills development as an external shock. Skill development is also influenced by schooling choices and early schooling performances, such as grade retention or track enrolment.

Higher cognitive and non-cognitive skill measures correlate with higher educational attainment and better outcomes. Individuals choose whether to obtain a secondary education diploma ($D_8(\kappa_8)$ with $\kappa_8 = \kappa_2 \in \mathcal{K}_2$). If students obtain a degree different than a lower secondary education ($D_8(\kappa_8) > 1$), they can enrol in tertiary education ($D_9(\kappa_9)$). After enrolling ($D_9(\kappa_9) = 1$), they can obtain a diploma ($D_{10}(\kappa_{10})$). At last, individuals

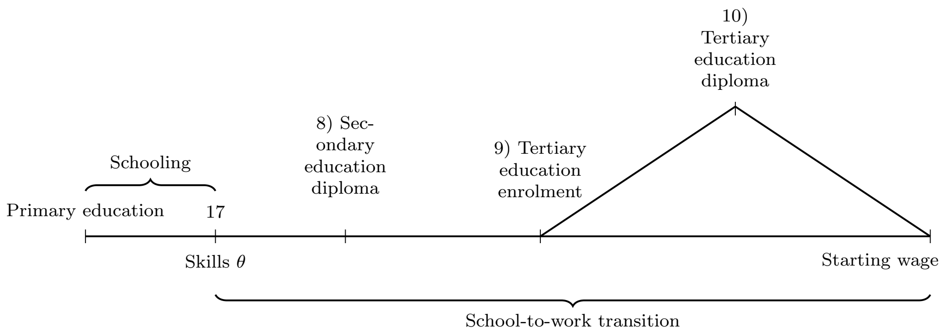


Figure 6: Model: School-to-work Transition

choose to enter the labour market after education ($D_{11}(\kappa_{11})$) and receive a starting log hourly wage ($t = 12$). $D_t(\mathcal{K}_t)$ for $t \in \{1, 3, 8, 9, 10, 11\}$ are binary choices, which are $\kappa_t = \kappa_1 \in \mathcal{K}_1 = \{0, 1\}$.

I use a flexible specification of the latent utility function regarding discrete choices. Let the latent utility function for individual i be denoted as $U_{it\kappa_t}$. $U_{it\kappa_t}$ depend on time-unvarying exogenous variables (X_i), time-varying local labour market conditions (L_{it}), t-specific endogenous outcomes (Z_{it}), and a residual term, v_{it}, that captures an unobserved component from the econometrician point of view. I approximate this latent utility function $U_{it\kappa_t}$ to be a linear function:

$$U_{it\kappa_t} = \beta_{0t} + \beta_{Xt}X_i + \beta_{Lt}L_{it} + \beta_{Zt}Z_{it} + v_{it} \text{ for } t \in \{1, 2, 3, 4, 8, ..., 11\} \tag{3}$$

The discrete choices of the model are characterized by the maximization of a latent utility variable $U_{it\kappa_t}$.

$$D_t(\mathcal{K}_t) = \underset{\kappa_t \in \mathcal{K}_t}{\text{argmax}} \left(U_{it\kappa_t} \right) \text{ for } t \in \{1, 2, 3, 4, 8, ...11\} \tag{4}$$

On the other hand, regarding continuous outcomes, which are skills and starting wages, I utilize a linear function:

$$Y_{it} = \beta_{0t} + \beta_{Xt}X_i + \beta_{Lt}L_{it} + \beta_{Zt}Z_{it} + v_{it} \text{ for } t \in \{5, 6, 7, 12\} \tag{5}$$

Log hourly wages $Y_{i12} = \log(wage)_i$ at the first job after the end of education are modelled as:

$$\log(wage)_i = \beta_{0t} + \beta_{Xt}X_i + \beta_{Lt}L_{it} + \beta_{Zt}Z_{it} + v_{it} \text{ for } t \in \{12\} \tag{6}$$

I use starting log hourly wages by removing the possible influence of endogenous work experience. Z_{i12} also includes a set of skill complementarities, dynamic complementarities with educational outcomes, and skill-ability complementarities.

3.3 Unobserved Heterogeneity and Identification

Unobserved heterogeneity is crucial in dynamic treatment effects models, because it induces correlation across different choices, addressing the issue of dynamic selection. This literature calls this matching on unobservables, relative to matching solely on observables (Heckman and Navarro, 2007). In this specific setting, exogenous unobserved heterogeneity may be considered a measure of ability, which defines a differential for individuals in developing skills and having improved schooling or labour market outcomes.[11] I apply the following factor structure to the error term v_{it}:

$$v_{it} = \gamma_{mt}\eta_m + \varepsilon_{it}, \tag{7}$$

in which η_m is a random effect, independent of ε_{it}, and independent across individuals, and in which γ_{mt} is an outcome-specific parameter related to this random effect. This random effect captures unobserved determinants and is assumed independent of the observed exogenous individual characteristics. Following the literature on dynamic discrete choice models, I use a finite mixture distribution to model the unobserved random variable η_m (cf. Heckman and Singer, 1984; Arcidiacono, 2004).[12] I assume this distribution to be characterized by an a priori unknown number of M different heterogeneity types with type-specific heterogeneity parameters γ_{mt} for each outcome. This avoids relying on strong distributional assumptions and, therefore, also minimizes any bias resulting from misspecification in this respect (Heckman and Singer, 1984; Hotz et al., 2002).

I use a set of strategies to identify unobserved heterogeneity and correctly identify the model. First, the panel dimension of the data, specifically the autocorrelation of measured skills, educational choices, and wages given observed covariates, plays a crucial

[11] Indeed, individuals are assumed to belong to one of the m unobserved types, and as such, they possess a type-specific constant that positively or negatively influences each outcome. For instance, individuals in the second unobserved type may have a positive unobserved factor (i.e., type-specific constant), resulting in higher average wages than individuals in the first unobserved type. This may be interpreted as individuals of the second type being more able, motivated, or productive in the work setting.

[12] It enters each likelihood contribution as a constant parameter, but, given the probability weight for each observation, it becomes a dummy capturing type-specific shocks.

role in identifying the returns associated with skills while accounting for unobserved heterogeneity and dynamic selection. Secondly, including exclusion restrictions as variables that affect choices but are not included in the subsequent outcomes is crucial for addressing the selection bias, following Heckman and Navarro (2007), Heckman et al. (2016, 2018a, 2018b), and Ashworth et al. (2021). I impose exclusion restrictions during the schooling phase to identify exogenous ability, which is innate and assumed to impact all choices and outcomes in the model. I start with school recommendations influenced by the exogenous state-year variation in binding reforms made by federal states in Germany (Grewenig, 2022). For some pupils, recommendations they receive are binding: e.g. states with binding teacher recommendations have a selective tracking system since children can only attend academic schools if they have a recommendation. The effect of having either a binding or a non-binding system has an effect on how a teacher recommends a track. However, this does not affect future outcomes except through school recommendations. School recommendations are crucial in our model: they influence school track enrolment but do not influence later outcomes if not through school enrolment. There is a large unexplained variation among individuals who, for instance, received a lower school recommendation but still enrol in upper schooling and managed to develop higher skills, e.g. cognitive. In my model, unobserved heterogeneity captures this variation, and is interpreted as a source of ability differential among individuals. It reflects differences in factors such as grit, motivation, pure ability, and other aspects influencing skill development and future outcomes. School recommendation impacts school enrolment, as either way (binding or non-binding reforms), it will induce individuals into a specific track. Lastly, as the unemployment rate at the state level is a time-variant variable and t-specific, it works as an exclusion restriction for the subsequent outcomes (cf. Heckman et al., 2018a, 2018b; Ashworth et al., 2021). This is central in identifying the distribution of potential wages and the parameters from the realized wages of those employed in a first job (Ashworth et al., 2021).

3.4 Likelihood Function

I map each endogenous variable of the model to a likelihood function ℓ_{it}:

$$\ell_{it} = \begin{Bmatrix} \frac{1}{\sigma_o}\Phi(\frac{Y_{it}}{\sigma_o}) & \text{if continuous} \\ \Lambda(U_{it\kappa_t}) & \text{if discrete} \end{Bmatrix} \qquad \text{for } t \in T, \tag{8}$$

where the assumptions are that the idiosyncratic shocks (ε_{it}) for continuous variables are distributed $\mathcal{N}(0,1)$, and that binary and ordered outcomes have a type I extreme value distribution.

Without including unobserved heterogeneity ($v_{it} = \varepsilon_{it}$), the likelihood $\mathcal{L}_i$ of the model is constructed using the full set of outcomes and it is fully separable:

$$\log(\mathcal{L}_i) = \sum_{i=1}^{I} \log\left(\prod_{t=1}^{T} \ell_{it}\right) = \sum_{i=1}^{I}\sum_{t=1}^{T} \log(\ell_{it}) \tag{9}$$

Therefore, it can be estimated in separate stages, with consistent results.[13] However, when introducing unobserved heterogeneity ($v_{it} = \gamma_{mt}\eta_m + \varepsilon_{it}$), the likelihood is not separable anymore and the optimization issue becomes:

$$\{\hat{\gamma}, \hat{\pi}\} = \arg\max_{\gamma,\pi} \sum_{i=1}^{I}\left[\sum_{m=1}^{M} \pi_m \log\left(\prod_{t=1}^{T} \ell_{it}(H_t, \gamma_{mt}, \varepsilon_t)\right)\right], \tag{10}$$

where there is a number of M unobserved types, and I need to estimate both the probability types associated to each unobserved type m, π_m, and the m specific parameter for each outcome t. H_t includes at each stage X, L_t, Z_t. At this stage, the likelihood is not separable anymore because of the correlation induced by γ and π across different choices. I estimate this likelihood by using the Expectation Maximization (EM) Algorithm. More details about the estimation strategy using the EM Algorithm are included in Section B.1 in the Appendix. I evaluate the model optimization and the number of heterogeneity types in Section B.2 in the Appendix.

[13]This is by assuming that I do not have a problem of selection and, therefore, that earlier outcomes do not influence future outcomes.

4 Results

Using the results from the cohort-specific models, I can compute different counterfactual simulations and retrieve the treatment effects. See Section B.3 in the Appendix for the definition of the treatment effects. See Section B.4 in the Appendix for further information on the simulations for estimating counterfactuals.

4.1 Changes in Returns to Skills

In this section, I estimate changes in the returns to skills across cohorts, using two demographic cohorts, M (1987-1995) and Z (1996-2003). The analysis focuses on estimating the direct and total effects resulting from one standard deviation (σ) increase in cognitive, diligence, and social skills.[14]

For each skill θ^j, with $j \in \{c, s, d\}$, I compute the direct, $g = direct$, and the total, $g = total$, effect of a σ increase in each skill:

$$\Delta^g_{\theta^j,d} = f^w_m(\theta^j_i + \sigma) - f^w_m(\theta^j_i) \tag{11}$$

Table 5: Wage Returns to a σ Increase in Multidimensional Skills

	(1) M (1987-1995)		(2) Z (1996-2003)	
	Direct	Total	Direct	Total
Skills	0.052	0.112**	0.123*	0.187***
	(0.044)	(0.046)	(0.063)	(0.057)
Cognitive skills (θ^c)	0.044**	0.105***	0.055*	0.090***
	(0.020)	(0.022)	(0.030)	(0.030)
Diligence skills (θ^d)	0.025	0.038	-0.017	0.007
	(0.018)	(0.023)	(0.028)	(0.029)
Social skills (θ^{sc})	0.021	0.002	0.056**	0.066**
	(0.020)	(0.025)	(0.027)	(0.029)

Notes: demographic cohort M includes individuals born between 1987 and 1995, while demographic cohort Z includes individuals born between 1996 and 2003. "Skills" is the combined return to a σ increase in all skills (θ^c, θ^d, and θ^s), including the effect of complementarities.

Both direct and total returns, $\Delta^g_{\theta^j,d}$, are included in Table 5. In general, I observe

[14] Therefore, the effect should always be interpreted as the effect of one standard deviation (σ) increase of skills.

evidence of higher returns to skills: from about a total (direct) return of 11.2% (5.2%) for individuals in demographic cohort M (1987-1995), I observe a total (direct) return of 18.7% (12.3%) for individuals in demographic cohort Z (1996-2003). Cognitive skills, θ^c, show the largest direct and total returns of, respectively: 4.4% and 10,5 % for individuals in M and 5.5% and 9% for individuals in Z. These are stable across cohorts. In both cases, the indirect effect of education is substantial: 6.1% for M and 3.5% for Z. Therefore, the importance of cognitive skills is also associated with increased access to further education, with returns through this channel. The returns to diligence skills, θ^d, conditional on both θ^c and θ^s, are not significant. In terms of direct effects, diligence skills are associated with a 2.5% wage return for M, while a negative return of -1.7% is associated with Z. Interestingly, the returns to social skills are not significant for individuals in M, but are significant for individuals in Z: a σ increase in social skills is associated with a 6.6% increase in hourly wages for these individuals. Most of this effect is accounted for by direct effects, without considering the indirect effect of education. Therefore, this may be interpreted as a pure labour market change, as captured by the model of Deming (2017). When estimating returns to endogenous skills, without accounting for exogenous ability, I obtain different results, as in Table 6. When including exogenous ability, I find significant

Table 6: Wage Returns to a σ Increase in Multidimensional Skills

	M (1987-1995)				Z (1996-2003)			
	Without exogenous ability		Exogenous ability		Without exogenous ability		Exogenous ability	
	Direct	Total	Direct	Total	Direct	Total	Direct	Total
Skills	-0.031	0.020	0.052	0.112**	0.129*	0.189***	0.123*	0.187***
	(0.053)	(0.054)	(0.044)	(0.046)	(0.072)	(0.065)	(0.063)	(0.057)
Cognitive skills (θ^c)	0.010	0.074**	0.044**	0.105***	0.010	0.047	0.055*	0.090***
	(0.026)	(0.029)	(0.020)	(0.022)	(0.039)	(0.038)	(0.030)	(0.030)
Diligence skills (θ^d)	-0.017	-0.009	0.025	0.038	0.008	0.033	-0.017	0.007
	(0.025)	(0.029)	(0.018)	(0.023)	(0.034)	(0.035)	(0.028)	(0.029)
Social skills (θ^s)	0.013	-0.011	0.021	0.002	0.081**	0.091**	0.056**	0.066**
	(0.028)	(0.033)	(0.020)	(0.025)	(0.035)	(0.036)	(0.027)	(0.029)

Notes: demographic cohort M includes individuals born between 1987 and 1995, while demographic cohort Z includes individuals born between 1996 and 2003. "Skills" is the combined return to a σ increase in all skills (θ^c, θ^d, and θ^s), including the effect of complementarities. I estimate returns to a σ increase in each skill without exogenous abilities, by simulating the results with only one unobserved type in the model. When including two unobserved types, I define the results as including exogenous abilities.

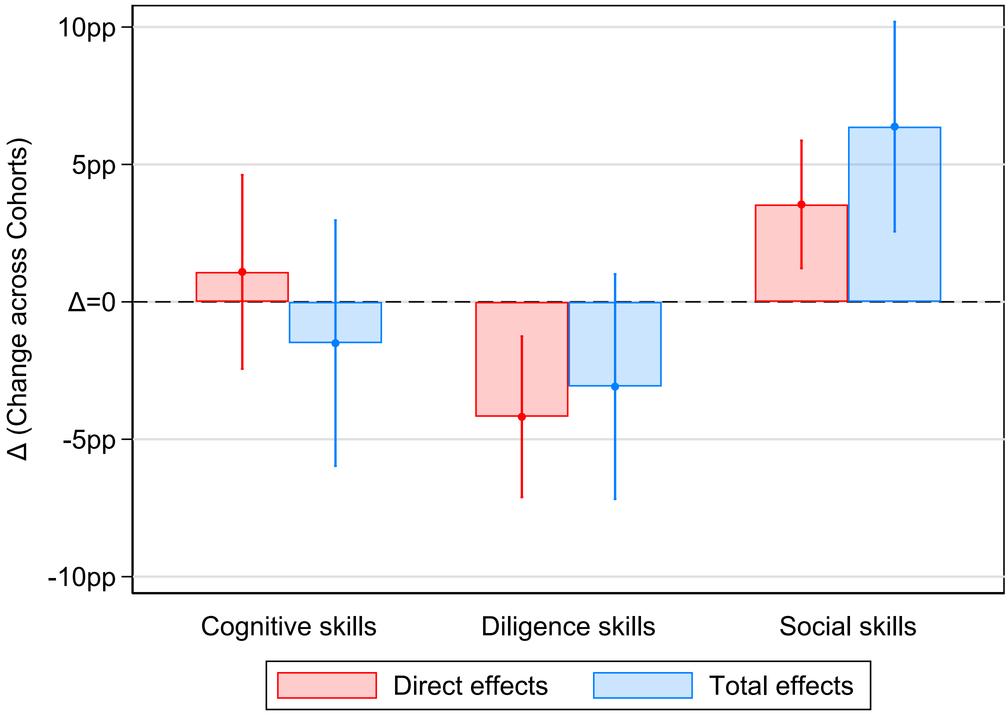
and positive returns to cognitive skills. On the other side, including exogenous ability reduces the positive and significant effect of social skills for demographic cohort Z, which remains positive.

Using these returns, I can compare the changes across cohorts M and Z:

$$\Delta^g_{\theta^j} = \Delta^g_{\theta^j,Z} - \Delta^g_{\theta^j,M} \tag{12}$$

The results are included in Figure 7. One of the major components driving increasing returns to skills is the higher returns to social skills (Deming, 2017).

Figure 7: Changes (Δ^g_a) in Wage Returns to Multidimensional Skills across Cohorts



Notes: Changes in wage returns are computed in percentage points (pp). This is the change (Δ) computed across demographic cohorts. $\Delta = 0$ represents no change across cohorts in the returns to skills.

Figure 7 shows the change in percentage points in wage returns to multidimensional skills across cohorts. Cognitive skills are stable over time and I do not find evidence of lower returns to cognitive skills. Moreover, I observe two interesting results. First, the return to social skills has increased across these two cohorts, consistent with Deming (2017). There is a change of 6.4 percentage points in total effects. Second, diligence skills show a downward trend in wage returns, with a negative change of 4.2 percentage points in direct effects. These results may unmask consistent heterogeneity based on the skill bundle of each individual. Overall, these results largely align with the prediction made by the model of Acemoglu and Autor (2011) in Section 2.4.

4.1.1 Changes in Complementarities and Heterogenous Effects

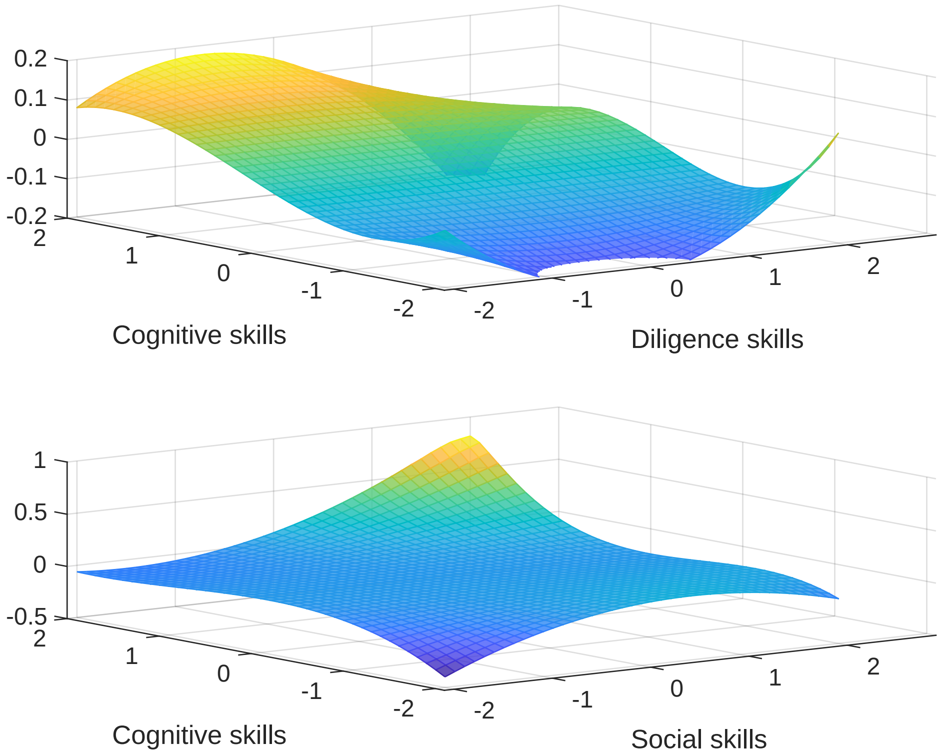
In this section, I document how complementarities between multidimensional skills have changed over time. The model includes substantial heterogeneity and complementarities, both dynamic complementarities and skill complementarities, with heterogeneous returns to skill and non-linearities. This allows me to estimate changes in returns considering selected bundles of skills. I compute the return to a σ increase in diligence (θ^d) and social (θ^s) skills, given cognitive (θ^c) skills at each point of the distribution. More specifically, I compute for $j \in \{d, s\}$:

$$\Delta^{n,nn}_{\theta^j,\theta^c,\theta^{-j}} = \frac{1}{I}\sum_{i=1}^{I}\Bigg(\bigg(f^w_{mZ}(\theta^j_{iZ} = nn + \sigma|\theta^c_Z = n, \bar{\theta}^{-j}_Z) - f^w_{mZ}(\theta^j_{iZ} = nn|\theta^c_Z = n, \bar{\theta} - Z^{-j})\bigg) - , \\ \bigg(f^w_{mM}(\theta^j_{iM} = nn + \sigma|\theta^c_M = n, \bar{\theta}^{-j}_M) - f^w_{mM}(\theta^j_{iZ} = nn|\theta^c_M = n, \bar{\theta}^{-j}_M)\bigg)\Bigg) \tag{13}$$

where both n and nn are included in $\{-2, ..., 2\}$. In this formula, θ^{-j} represents the remaining skill, when considering θ^j (e.g. in the computation for θ^d, $\theta^{-j} = \theta^s$). The output is a matrix represented in Figure 8.[15] Figure 8 shows two interesting results. First, there is a substantial increase in complementarities between social and cognitive skills (Deming, 2017). This is evident from Figure 8, where the largest changes in the returns to θ^s, are concentrated among θ^c and θ^s above the mean. Second, increasing complementarity between cognitive and diligence skills is concentrated on the left side of the diligence skill distribution. In Figure 8, the largest change in returns is concentrated between individuals with cognitive skills larger than 1σ and individuals with diligence skills comprised between -2σ and 0. Figure 9 further investigates this, by including the changes in returns to both diligence and social skills across the distribution for individuals with either low ($\theta^c < 0$) or high ($\theta^c > 0$) cognitive skills. In Figure 9, the horizontal black line ($\Delta = 0$) represents no changes across cohorts in the returns to a σ increase in skills. Further, Figure 9 includes the Δ across cohorts in returns for high ($\theta^c > 0$) and low ($\theta^c < 0$) cognitive individuals, respectively in red and blue. Therefore, each bar represents the change across cohorts in returns to a $+1\sigma$, at each point of the distribution,

[15] With the dimensions of n and nn. As I include two vectors from -2 to 2, using intervals of 0.1, this is a 41x41 matrix.

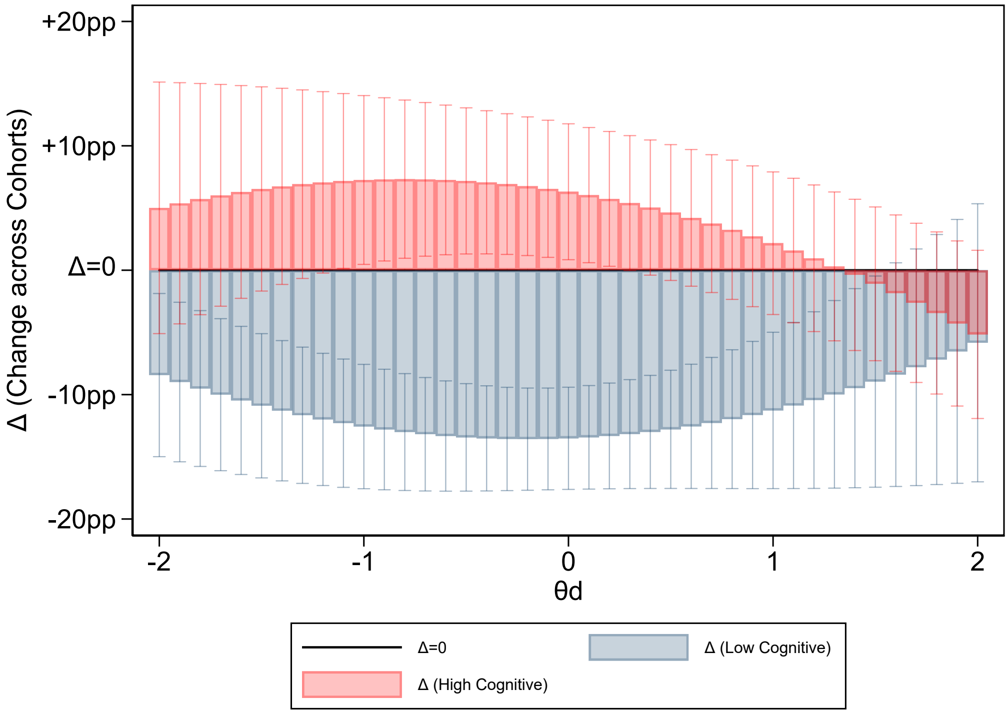
Figure 8: Distribution of Changes in Wage Returns to a σ Increase across Cohorts

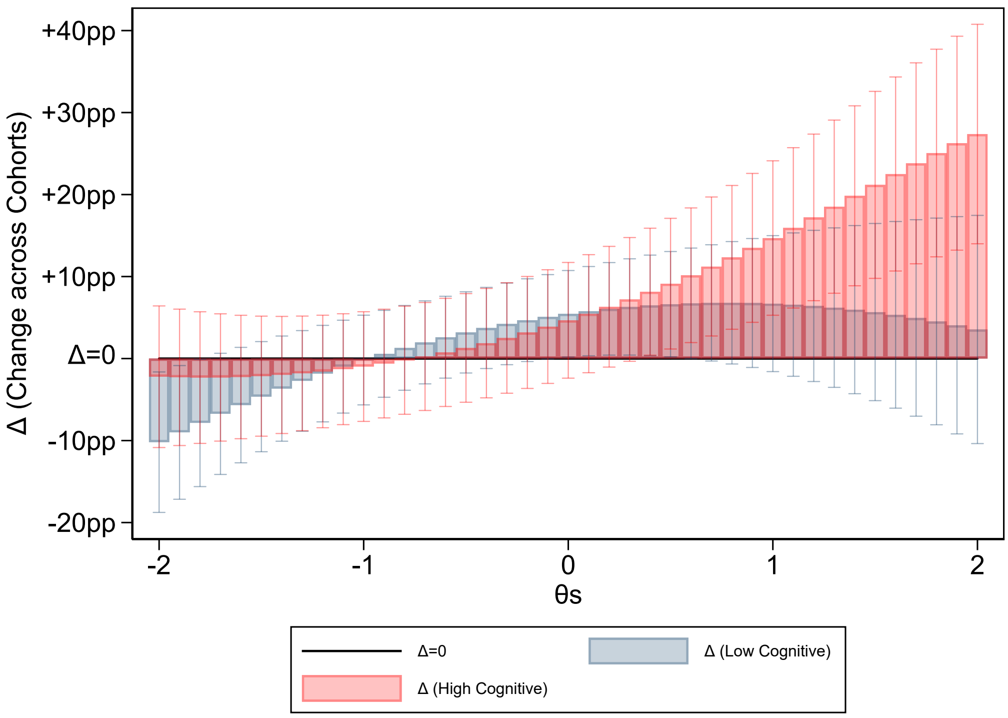


Notes: This graph is the result of a simulation for which we compute a σ increase at each point of the matrix computed using combinations of two skills while holding fixed the other skill (at mean). For each return, I compute the change across demographic cohorts. Skills are standardized to be distributed with mean 0 and standard deviation 1. All changes are expressed in percentage points.

while holding the other skill constant.

Figure 9: Changes (Δ) in Returns across Cohorts: Diligence (θ^d) and Social (θ^s) Skills across the Distribution for Low ($\theta^c < 0$) and High ($\theta^c > 0$) Cognitive Individuals





Notes: This graph includes the changes across cohorts in the return to skills at each point of the skill distribution while keeping the other multidimensional skills constant. You can find the formula used in the main text, alongside with a 3D graph showing the full result. I consider individuals with high ($\theta^c > 0$) or low ($\theta^c < 0$) cognitive skills, by averaging the changes across cohorts. Confidence intervals are computed at the 95% level. All confidence intervals are computed relative to $\Delta = 0$, i.e. no change across cohorts.

Individuals with high cognitive skills benefit from higher returns to diligence skills, except when the latter is well above the mean: there are no significant negative changes in returns to diligence skills for high-cognitive individuals. The downward trend in returns to diligence skills is driven by individuals with low cognitive skills, with large and negative changes in returns to diligence skills across the entire distribution. Regarding social skills, the relationship is not substantially different for individuals with different cognitive skills, but individuals with high cognitive skills benefit the most from higher returns to social skills when they have social skills above the mean. This highlights the importance of complementarities between social and cognitive skills. Individuals who have a comparative advantage in routine tasks (high diligence skills) essentially experience declining returns regardless of where they sort, as they have a comparative advantage to perform a set of tasks, which is declining (Acemoglu and Autor, 2011). In Table 7, I further show the heterogeneity in returns to a σ increase in each skill by considering different bundles of skills.[16]

Table 7: Changes (Δ) in Returns across Cohorts by Skill Bundle

		$\theta^d < 0$				$\theta^d > 0$			
		M (1987-1995)		Z (1996-2003)		M (1987-1995)		Z (1996-2003)	
		Direct	Total	Direct	Total	Direct	Total	Direct	Total
$\theta^c > 0$	Skills	0.017	0.076	0.142*	0.199**	0.102*	0.168***	0.149	0.211**
		(0.049)	(0.055)	(0.083)	(0.082)	(0.056)	(0.060)	(0.090)	(0.093)
	Cognitive skills θ^c	0.039*	0.100***	0.012	0.051	0.065**	0.121***	0.093**	0.130***
		(0.021)	(0.032)	(0.039)	(0.045)	(0.027)	(0.031)	(0.036)	(0.048)
	Diligence skills θ^d	-0.000	0.014	0.027	0.052	0.053**	0.070**	-0.006	0.015
		(0.021)	(0.034)	(0.036)	(0.043)	(0.026)	(0.035)	(0.041)	(0.050)
	Social skills θ^{sc}	0.016	-0.000	0.073**	0.085**	0.023	0.009	0.033	0.044
		(0.022)	(0.034)	(0.036)	(0.042)	(0.026)	(0.034)	(0.035)	(0.047)
$\theta^c < 0$	Skills	-0.007	0.042	0.107*	0.172***	0.108**	0.179***	0.112	0.179**
		(0.047)	(0.052)	(0.057)	(0.050)	(0.051)	(0.068)	(0.074)	(0.070)
	Cognitive skills θ^c	0.017	0.083**	0.015	0.049	0.056**	0.121***	0.101**	0.134***
		(0.025)	(0.033)	(0.038)	(0.038)	(0.028)	(0.046)	(0.039)	(0.042)
	Diligence skills θ^d	-0.005	0.001	-0.019	0.007	0.056**	0.071	-0.051	-0.027
		(0.025)	(0.034)	(0.033)	(0.035)	(0.026)	(0.050)	(0.041)	(0.044)
	Social skills θ^{sc}	0.018	-0.008	0.082**	0.091**	0.033	0.010	0.033	0.042
		(0.028)	(0.036)	(0.034)	(0.037)	(0.028)	(0.045)	(0.039)	(0.042)

Notes: This graph includes the treatment effects of a σ increase to each skill by different skill bundles. θ^j with $j \in J \in \{c, d, s\}$ represents cognitive, diligence, and social skills. "Skills" include the combined effect of a σ increase in each skill.

The latter analysis exclude the effect of one of the two non-cognitive skills for the sake of clarity. Therefore, in this following tables, I include the full skill bundle, with the relative complementarities effects. The analysis of Table 7 reveals a substitution effect occurring within the distribution of diligence skills: individuals with low diligence skills

[16] In Appendix C.1, I show Table 25, including the results for a different skill bundle, using θ^{sc}.

are benefiting from the increasing returns to social skills, while those with high diligence skills are experiencing a decline in their previously higher returns to diligence skills. This may be referred to as an offsetting effect of high diligence skills on the increasing returns to social skills. Individuals with lower diligence skills experience a significant increase in the returns to social skills, which is not true for those with higher diligence skills.

Table 8: Changes (Δ) in Returns across Cohorts by Skill Bundle (High Cognitive $\theta^c > 0$)

	Changes in returns			
	$\theta^c > 0, \theta^d < 0$		$\theta^c > 0, \theta^d > 0$	
	Direct	Total	Direct	Total
Skills	0.125***	0.123**	0.046	0.043
	(0.048)	(0.057)	(0.051)	(0.061)
Cognitive skills θ^c	-0.027	-0.050	0.028	0.009
	(0.026)	(0.041)	(0.028)	(0.044)
Diligence skills θ^d	0.028	0.037	-0.059**	-0.055
	(0.024)	(0.043)	(0.025)	(0.042)
Social skills θ^s	0.058***	0.086**	0.010	0.035
	(0.022)	(0.039)	(0.020)	(0.037)

Notes: For each return, I compute the change across demographic cohorts. Skills are standardized to be distributed with mean 0 and standard deviation 1. θ^j with $j \in J \in \{c, d, s\}$ represents cognitive, diligence, and social skills. All changes are expressed in percentage points. All confidence intervals are computed relative to $\Delta = 0$, i.e. no change across cohorts.

Table 8 shows the changes (percentage points) for individuals with high cognitive skills. In this case, there is a strong change in returns for individuals with high cognitive and low diligence, as in Figure 9. I do not find such a strong change in returns to social skills for individuals high in cognitive and diligence skills. At last, individuals with high cognitive and diligence skills experience a negative change in return to diligence skills.

I further investigate this finding in Table 9. I compute the same change in returns for individuals holding a skill bundle with low cognitive skills. Table 9 illustrates a noteworthy observation: the decline in returns to diligence skills is even more pronounced among individuals with low levels of cognitive and high levels of diligence skills. These individuals experience a significant decrease of 10.8 percentage points in return to diligence skills. Interestingly, individuals with low cognitive abilities but high diligence skills do not benefit from increasing returns to skills. They are also more likely to find themselves in low-skilled routine jobs. Individuals with lower levels of both cognitive and diligence

Table 9: Changes (Δ) in Returns across Cohorts by Skill Bundle (Low Cognitive $\theta^c < 0$)

	Changes in returns			
	$\theta^c < 0, \theta^d < 0$		$\theta^c < 0, \theta^d > 0$	
	Direct	Total	Direct	Total
Skills	0.115***	0.130***	0.000	0.004
	(0.022)	(0.038)	(0.064)	(0.043)
Cognitive skills θ^c	-0.002	-0.034	0.013	0.045
	(0.017)	(0.034)	(0.053)	(0.031)
Diligence skills θ^d	-0.014	0.006	-0.098*	-0.108***
	(0.015)	(0.030)	(0.052)	(0.027)
Social skills θ^s	0.064***	0.099***	0.032	0.000
	(0.013)	(0.030)	(0.049)	(0.022)

Notes: For each return, I compute the change across demographic cohorts. Skills are standardized to be distributed with mean 0 and standard deviation 1. θ^j with $j \in J \in \{c, d, s\}$ represents cognitive, diligence, and social skills. All changes are expressed in percentage points. All confidence intervals are computed relative to $\Delta = 0$, i.e. no change across cohorts.

skills actually benefit considerably from the increasing returns to social skills. This leads to an overall rise in skill returns, primarily driven by the increasing returns to social skills. Additionally, the offsetting effects of high diligence skills remain consistent among individuals with low cognitive abilities.

Overall, these findings suggest that a bundle with high diligence skills may not be associated with increasing returns to skills. This is most likely connected to the fact that conditional on social skills, individuals high in diligence skills have a comparative advantage in performing routine tasks, as I empirically test in Section 4.1.2. This is the most important mechanism to explain the negative change in returns to diligence skills and its offsetting effects on increasing returns to social skills.

4.1.2 Occupational Sorting

The findings of previous sections are largely in line with the prediction of the model included in Acemoglu and Autor (2011). In this section, I show that individuals with higher diligence skills hold a comparative advantage in performing routine tasks. This explains why returns to diligence skills have diminished, and a bundle with higher diligence skills has an offsetting effect on increasing returns to skills. Using the task measures extracted from ESCO, I categorize each occupation with a binary variable indicating if it has a task content above the 50 percentile. Therefore, I estimate a dynamic model by estimating the effects of a σ increase for a higher probability of sorting into an occupation that is task intensive in either social, routine, or cognitive. The results are included in Table 10.

Table 10: Occupational Sorting (Tasks and Skills)

	Occupational Sorting		
	Social	Routine	Cognitive
Cognitive skills (θ^c)	0.044**	0.023	**0.050*** **
	(0.017)	(0.018)	**(0.013)**
Diligence skills (θ^d)	0.070***	**0.051*** **	0.074***
	(0.019)	**(0.016)**	(0.015)
Social skills (θ^s)	**0.084*** **	0.017	0.094***
	(0.017)	(0.016)	(0.012)

Notes: I classify each occupation with a binary outcome, where 1 defines an occupation with task content above the 50 percentile in either social, routine, or nonroutine analytical (cognitive) task. The model is re-estimated using these three binary outcomes at the place of starting wages.

Indeed, individuals with high diligence skills have a large comparative advantage in performing routine tasks. A σ increase in diligence skills generates a greater sorting into occupation intensive in routine tasks, which is not evidenced for other skills. This generates an overall reduction in returns to diligence skills for all individuals, conditional on their bundle of skills. Therefore, we observe a large decline in wage returns to diligence skills, especially for individuals with lower cognitive skills. Moreover, I observe an offsetting effect of diligence skills on increasing returns to social skills: individuals with high diligence skills do not experience an increasing return to these skills.

4.2 Development of Multidimensional Skills

In this section, I estimate the returns to early schooling regarding skill development. It is clear, from both Deming (2017) and Deming (2023), that skill development for both θ^d and θ^s is a crucial topic of further research. Using my model, I can estimate a simple treatment effect for various early schooling outcomes on skills.

In Table 11, I estimate the treatment effects associated with grade retention in both primary and secondary education for both cohorts. In both cases, grade retention in primary and secondary education implies a large loss in both cognitive and diligence skills: for demographic cohort M, respectively, 52% (26%) of a standard deviation for primary

Table 11: Development of Multidimensional Skills

	Grade retention:	M (1987-1995) Skills: Cognitive (θ^c)	Diligence (θ^d)	Social (θ^s)	Z (1996-2003) Skills: Cognitive (θ^c)	Diligence (θ^d)	Social (θ^s)
ATE	Primary Education	-0.528***	-0.205**	**-0.189****	-0.800***	-0.402***	**-0.317*****
		(0.087)	(0.082)	**(0.094)**	(0.093)	(0.091)	**(0.103)**
	Secondary Education	-0.261***	-0.414***	**-0.003**	-0.228***	-0.233***	**0.069**
		(0.058)	(0.066)	**(0.058)**	(0.060)	(0.066)	**(0.066)**
ATT	Primary Education	-0.560***	-0.184**	**-0.145**	-0.754***	-0.427***	**-0.344*****
		(0.086)	(0.090)	**(0.090)**	(0.090)	(0.093)	**(0.092)**
	Secondary Education	-0.287***	-0.418***	**-0.058**	-0.265***	-0.246***	**0.031**
		(0.061)	(0.064)	**(0.061)**	(0.065)	(0.069)	**(0.071)**
ATNT	Primary Education	-0.526***	-0.206**	**-0.193****	-0.805***	-0.399***	**-0.314*****
		(0.089)	(0.083)	**(0.096)**	(0.097)	(0.095)	**(0.107)**
	Secondary Education	-0.256***	-0.413***	**0.007**	-0.222***	-0.231***	**0.076**
		(0.059)	(0.067)	**(0.060)**	(0.061)	(0.066)	**(0.066)**

Notes: causal estimates of the effects of grade retention on skill development using the dynamic model. Average Treatment Effects (ATE) computes the effect for the full population, Average Treament Effects on the Treated (ATT) computes the impact on individuals who have been retained in either primary or secondary education. Average Treatment Effects on the Non-Treated (ATNT) computes the impact for individuals who have never been retained in education. Effects are expressed in σ standard deviations.

(secondary) education, while a 20% (41%) of an SD for primary (secondary) education. This is also in line with the results for demographic cohort Z: 80% (22%) of a standard deviation for primary (secondary) education for cognitive skills, while a 40% (23%) of an SD for primary (secondary) education for diligence skills. The evidence on social skills is different. Grade retention in primary education generates a loss in social skills in both cohorts of around 18% of a σ and 31% of a σ. However, grade retention in secondary education does not generate any significant effect on social skills: for demographic cohort M the effect is close to zero, while for cohort Z, the effect is positive but insignificant.

5 Robustness Checks

5.1 Task Content without Latent Factors

As a first robustness check, I estimate the task content of each occupation without relying on latent factors but using continuous measurements. Each skill group is associated with a task by using broader skill groups, and these are aggregated into continuous measurements (then standardized) used for defining each occupation. The definition of these continuous measurements is included in Appendix, Section D.1. Figure 13 in Appendix is produced with the same procedure as Figure 2, but using this continuous measurement. Overall, the patterns are similar, with occupation intensive in social tasks increasing substantially over the period. This is mirrored by a large decline in occupation intensive in routine tasks. The main difference relates to non-routine analytical (cognitive) task, that, using these measurements, seems to rise together with social tasks. In Figure 19, included in Appendix D.1, I perform again the same calculations of Figure 3, while using these continuous measurements. The results are, again, largely in line with the results of Figure 3. The only difference lies in the decline over the last half-decade for occupation intensive in social and non-routine tasks.

5.2 Changes in Present Value Earnings to Skills

In this paper, I use starting wages to rule out the effect of different accumulation of work experience among individuals with different skill bundles. Moreover, I do not account for endogenous work experience accumulation. To check the robustness of my results on starting wages, I can also consider the adjusted present value of earnings, computed using all the observations on wages for each individual. The results are included in Table 27, with both direct and total returns from a σ increase in each skill and changes in percentage points across cohorts for each skill. The results are noisier in terms of precision, but they indicate similar conclusions, with an increase of around seven percentage points for returns to social skills and stable changes in returns to cognitive skills. The less precise estimates could be determined by the role of work experience in defining present value and the issue of attrition since I do not observe the same number of years after the starting wage for each individual.

5.3 Excluding Individuals by Year

The definition of the two demographic cohorts may appear arbitrary, and it is worth noting that individuals on the fringes of the cohort definition may have similar characteristics. To ensure the robustness of my results, I exclude individuals from the years that fall on the boundaries of the demographic cohort definition. Therefore, I exclude individuals born in 1994, 1995, and 1996. Afterwards, I re-estimate the model and analyze the outcomes, as presented in Table 12 in Appendix. This shows again a large increase in the returns to social skills, estimated to be around seven percentage points for the total returns. Overall, there are no sizeable changes for both cognitive and diligence skills. The results are in line with Figure 7.

Table 12: Results Excluding Individuals by Year

	(1) Changes	
	Direct	Total
Cognitive skills (θ^c)	0.002	-0.039
	(0.026)	(0.029)
Diligence skills (θ^d)	0.007	-0.011
	(0.016)	(0.023)
Social skills (θ^s)	0.049**	0.070***
	(0.021)	(0.026)

5.4 Changes in Returns to Multidimensional Skills

In this section of robustness checks, I estimate a model without using latent factors but by including a set of multidimensional skills, such as the Big 5 personality traits and other dimensions. This is a similar approach to what I perform for task content in Section 5.1. I begin with Table 28 in Appendix, where I compute the wage return to a σ increase for cognitive and non-cognitive skills.[17] While cognitive skills exhibit a clearly positive effect on both direct and total effects, the impact of non-cognitive skills is less evident. There is a 7.3 percentage point increase for cognitive skills, whereas non-cognitive skills exhibit a more significant increase of 14.6 percentage points. This represents a difference of nearly 7.3 percentage points, favouring non-cognitive skills over cognitive skills. On the other hand, when considering the change in direct effects without accounting for the impact of education, a strong increase of 13.4 percentage points is observed for cognitive skills, while the increase of 6.4 percentage points for non-cognitive skills is not statistically significant.

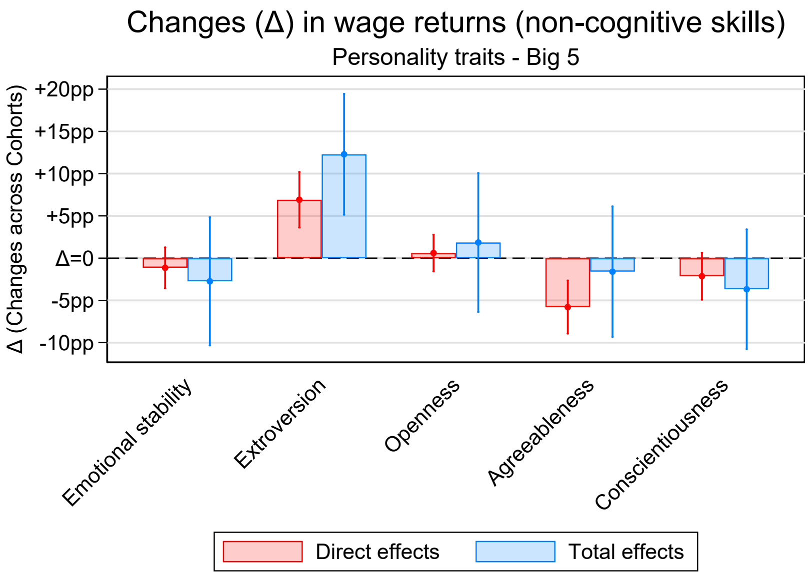
Figure 20 in Section D.3 in the Appendix provides an overview of the changes in wage returns resulting from a σ increase in each cognitive skill across cohorts. When considering the total effects, both verbal and math abilities have a sustained return to skills across cohorts M and Z respectively: 5.48% vs. 4.6% for verbal and 6.5% vs. 6.5% for math. Analyzing changes across cohorts, there is no evidence of significant variations in total returns on these skills. The returns have remained relatively stable over the past decades. Indeed, when analyzing the direct effects, there is no observable change in verbal abilities (2.6% vs. 2.9%), whereas math abilities demonstrate a significant increase

[17]In this setting, I do a counterfactual scenario where there is a σ increase in each skill, included in either cognitive or non-cognitive skills.

in returns (2.36% vs. 5.82%). The majority of changes regarding the returns on cognitive skills occurred at the labor market level, with minimal differences observed within the educational setting.

Figure 10 includes the change across cohorts in returns to a σ increase in each skill.

Figure 10: Changes in Wage Returns



Notes: Change, Δ_a^g, in wage returns across cohorts expressed in percentage points (p.p.). The change is the difference between cohort Z and M in the wage return to a σ increase in each specific skill. Direct effects do not include the indirect effects of education. Total effects include the composite effect of direct and indirect effects of a σ increase.

When considering total effects, the sizeable increase in non-cognitive skills returns is mostly associated with extroversion, among personality traits. This validates our result using latent factors, as extroversion highly indicates greater social skills.[18] Relative to non-cognitive skills, conscientiousness is one of the personality traits mainly associated with my factor representing diligence factors. This displays a downward trend, which is not significant. Results for other diligence skills are contained in Section D.3 in Appendix.

6 Conclusions

This paper analyzed which skills are experiencing a rising (falling) demand, and as a result, yielding higher (lower) returns over time. To do this, I analyze the evolution of task content of occupations and changes in returns to multidimensional skills in Germany

[18]The latent factor interpreted as social skills is constructed by normalizing one of the measures for building the latent factor used in the Big 5 personality traits literature, measuring extroversion.

over a period from 1984 to 2020. I employ a novel measure of task content based on ESCO to proxy skill demand. Using a latent factor approach, I reduce the dimensionality and categorize occupations based on their task content in routine, social, and cognitive tasks. Employment share surged by 18 percentage points for occupations emphasizing social skills, regardless of their cognitive task content.

Relative to Deming (2017) and Edin et al. (2022), I account for unmeasured ability differences and estimate direct and total effects. I do this by developing a new dynamic model of endogenous multidimensional skills and exogenous unmeasured ability. To the best of my knowledge, this is one of the first papers estimating returns to endogenous skills while accounting for unobserved heterogeneity, interpreted as innate ability.

I show a significant increase of 6.4 percentage points in the returns to social skills. This is paired with a negative change in returns to diligence skills, driven by low cognitive individuals. High diligence skills offset higher returns to skills: I find no evidence of higher returns to social skills for individuals with high diligence skills. This is especially true for low-cognitive individuals, indicating that low-cognitive-high-diligence, having a strong comparative advantage in routine-intensive occupations, are particularly affected by these trends due to routine task displacement (Acemoglu and Restrepo, 2022). This is mainly in line with Deming (2017) and the growing importance of social skills in the labour market: over time, low-cognitive individuals are better off developing higher social skills than high diligence skills. This is also in line with polarization, where low-cognitive, low-skilled workers are forced out from middle-skilled jobs, with a higher content of routine tasks, to low-skilled service jobs, with a high content of social tasks. More generally, I observe a substitution from high returns to diligence skills to a high return to social skills. I also find a strong change in returns between social and cognitive skills at the upper tail of the skill distribution, highlighting a strong complementarity between these two skill dimensions. Lastly, I show that social skills may have a different development trajectory, rather than cognitive and non-cognitive skills, using findings on the effects of grade retention on skill development. In the future, as already highlighted by Deming (2017, 2023), there are promising topics to be examined on multidimensional human capital, such as the development of multidimensional skills, the impact of educational expansion (with a substantial effect on skill mismatch and overeducation), and the impact of novel technologies, such as artificial intelligence, which could replace cognitive tasks.

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A Data Appendix

I use data from ESCO and the GSOEP, including the complete panel data set from 1984 to 2020. In this section of the Appendix, I carefully describe the datasets and the resulting data used in my analysis.

A.1 ESCO Appendix

I investigate changes in the task content of occupations by linking the ESCO dictionary for each occupation to the GSOEP Dataset. The ESCO[19] serves as a comprehensive multilingual classification system for labour markets in Europe[20]. It is a dictionary that outlines, identifies, and categorizes professional occupations and relevant skills crucial for the European Union's labor market, education, and training sectors. It is a project of the European Commission used to harmonize labour markets in the EU. ESCO encompasses a collection of 3'008 occupation descriptions and 13'890 skills associated with these occupations, all of which have been translated into 28 languages. I use the entire dataset of ESCO and link skill groups to each occupation, such as they may either be essential or optional for each occupation (ISCO-08 4 digits). Each occupation is classified using a set of 101 broader skill groups, containing all 13'890 narrower skills. These skill requirement descriptions are broad and include many different narrower skills. As an example, each occupation may have skill requirements in "assembling and fabricating products", or "recruiting and hiring", as well as "operating mobile plant", or, also, "leading others". For instance, the latter skill group "leading others", described as *guide, direct and motivate others*, comprises narrower skills, such as "build team spirit", "delegate responsibilities", "lead others" and "motivate others". These skills can be further decomposed into narrower skills, such as "lead others", described as *guide and direct others towards a common goal, often in a group or team*, comprises a large set of narrower skills, such as "coordinate construction activities", or " manage production systems", or "supervise dental technician staff".[21] These narrower skills are considered either essential or optional for each occupation. Therefore, the narrow skill "coordinate construction activities" is essential for occupations, such as underwater construction supervisor, demolition super-

[19]See more details on the website of ESCO.

[20]ESCO: The ESCO-O*NET crosswalk represents a first successful attempt to connect two international standards by combining the use of artificial intelligence (AI) techniques with human validation.

[21]It is possible to recover the full list at this link.

visor, or bridge construction supervisor. I categorize each occupation using the full set of around 13'890 skills descriptions in the following way. For each occupation, I use the 2 digits (broader) skill groups and I define each occupation with a binary outcome if the occupation includes any of the narrower skill requirements included in a given (broader) skill group. Moreover, I also use the groups for the transversal skills and competences. In this way, I have a set of binary outcomes for each occupation, including complete information for each set of skill requirements. While having reduced greatly the number of skills requirements, going from around 13'000 detailed skill requirements to around 100 broader skill groups[22], I need to further reduce this dimensionality.

A.1.1 Measurement System for Tasks

In this section, I further reduce the dimensionality of ESCO, in order to obtain a limited amount of variables to describe the task content of occupation in Germany. The first step is to perform a Principal Component Analysis using 98 different broader groups selected from ESCO. From Figure 11, it is clear that 3 main components are explaining a large part of the variation, while from the 4th component, the added value is only marginal.

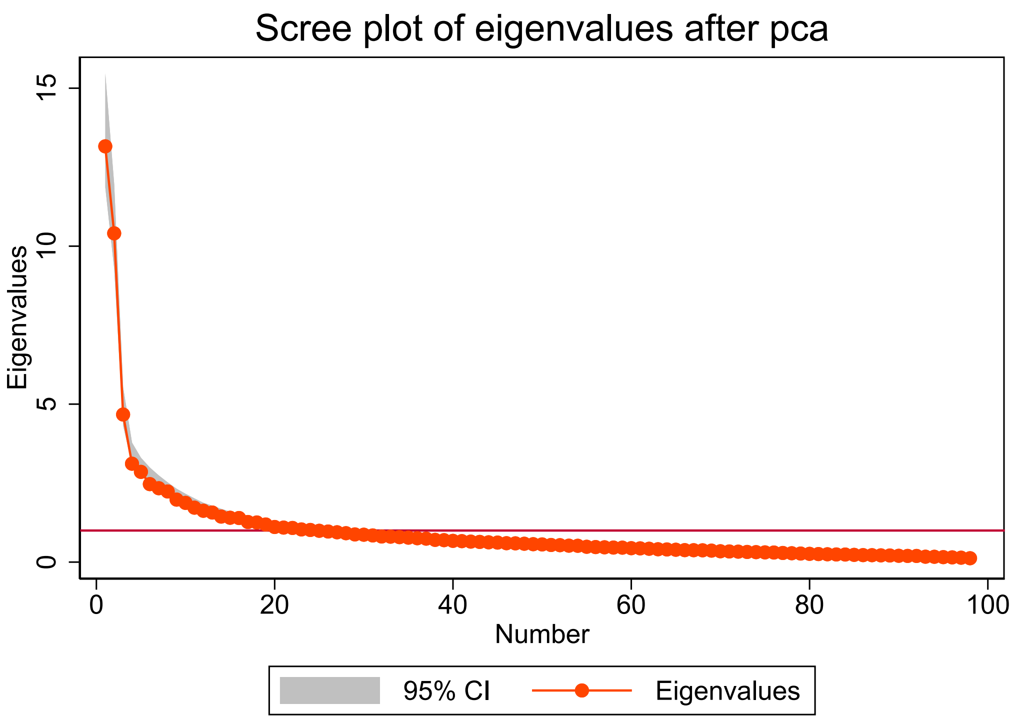


Figure 11: ESCO PCA Analysis

[22]It is possible to find the complete list of broader skill groups at this link.

The second step consists of both an Explanatory and a Confirmatory Factor Analysis (EFA and CFA). Starting with EFA, from Figure 12, the results are rather similar to the PCA, as shown in Figure 11, with three factors capturing a large part of the variation, and with only marginal value to further factors.

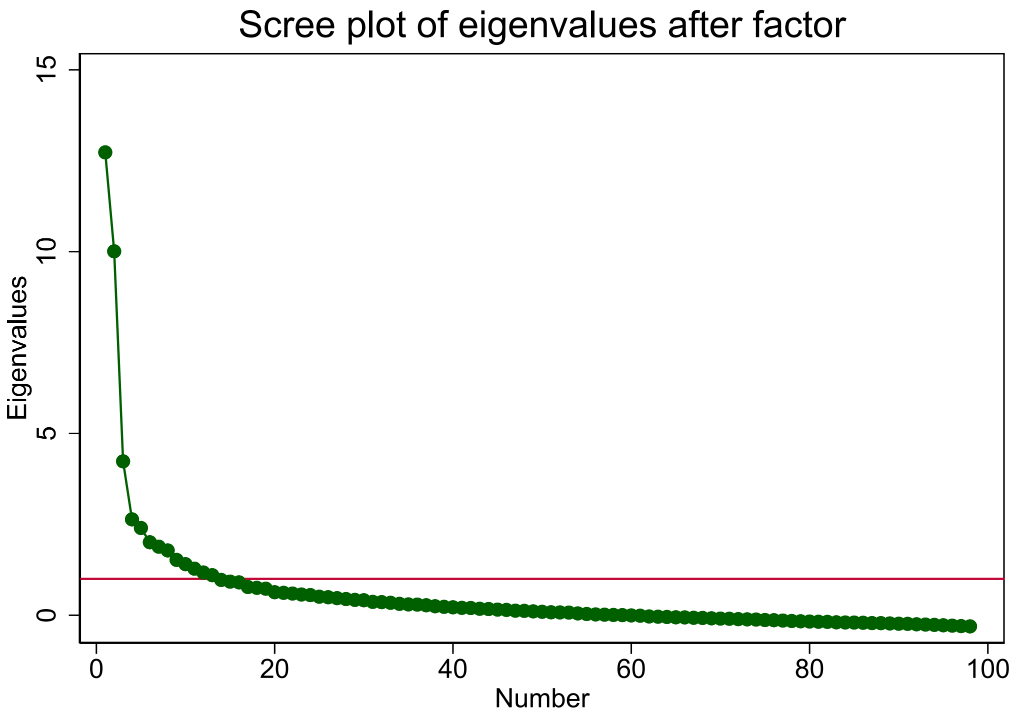


Figure 12: ESCO EFA Analysis

In Table 13, I show that the three main components extracted using PCA are highly correlated with the three main factors extracted using EFA.

Table 13: Correlation: PCA and EFA

	PCA Component 1	PCA Component 2	PCA Component 3
Factor 1	0.8672	0.1008	-0.4867
Factor 2	-0.0448	0.9912	0.1199
Factor 3	0.5187	-0.0868	0.8491

Of course, PCA and EFA are related, but there are important differences, for instance, regarding the measurement error. At this point, I use CFA to extract a series of three factors, based on the literature on the task-based approach, identifying three main tasks: routine, non-routine analytical (cognitive), and social (Deming, 2017). The main point is that these skill requirements all measure an underlying factor that ranks occupations based on their skill requirements. This measure is used to create a bundle of skill requirements or task content by occupation, that measures the different skill requirements. To identify the model, I use a set of dedicated measures for each factor and normalize the parameter to 1. I include both ESCO Skills and ESCO Transversal Skills and Competences. The model for the CFA is summarized in Table 14.

Measures		Social	Routine	Cognitive
ESCO Skills				
handling and disposing of waste and hazardous materials	*b*	x	x	x
moving and lifting	*b*	x	x	x
making moulds, casts, models and patterns	*b*	x	x	x
positioning materials, tools or equipment	*b*	x	x	x
tending plants and crops	*b*	x	x	x
transforming and blending materials	*b*	x	x	x
washing and maintaining textiles and clothing	*b*	x	x	x
cleaning	*b*	x	x	x
assembling and fabricating products	*b*	x	x	x
using hand tools	*b*	x	x	x
handling animals	*b*	x	x	x
sorting and packaging goods and materials	*b*	x	x	x
handling and moving	*b*	x	x	x
monitoring developments in area of expertise	*b*	x	x	x
monitoring, inspecting and testing	*b*	x	x	x
documenting and recording information	*b*	x	x	x
analysing and evaluating information and data	*b*	x	x	x
processing information	*b*	x	x	x
information skills	*b*	x	x	x
measuring physical properties	*b*	x	x	x
conducting studies, investigations and examinations	*b*	x	x	x
managing information	*b*	x	x	x
calculating and estimating	*b*			x
accessing and analysing digital data	*b*	x	x	x
setting up and protecting computer systems	*b*	x	x	x
using digital tools to control machinery	*b*	x	x	x
using digital tools for collaboration, content creation and problem solving	*b*	x	x	x
programming computer systems	*b*	x	x	x
working with computers	*b*	x	x	x
building and repairing structures	*b*	x	x	x
constructing	*b*	x	x	x
installing interior or exterior infrastructure	*b*	x	x	x
finishing interior or exterior of structures	*b*	x	x	x
building and developing teams	*b*	x	x	x
organising, planning and scheduling work and activities	*b*	x	x	x
developing objectives and strategies	*b*	x	x	x
recruiting and hiring	*b*	x	x	x
supervising people	*b*	x	x	x
allocating and controlling resources	*b*	x	x	x
making decisions	*b*	x	x	x
management skills	*b*	x	x	x
leading and motivating	*b*	x	x	x
performing administrative activities	*b*	x	x	x
installing, maintaining and repairing mechanical equipment	*b*	x	x	x
operating machinery for the extraction and processing of raw materials	*b*	x	x	x
operating machinery for the manufacture of products	*b*	x	x	x
using precision instrumentation and equipment	*b*	x	x	x
driving vehicles	*b*	x	x	x
installing, maintaining and repairing electrical, electronic and precision equip	*b*	x	x	x
operating watercraft	*b*	x	x	x
working with machinery and specialised equipment	*b*	x	x	x

operating aircraft	b	x	x	x
operating mobile plant	b	x	x	x
protecting and enforcing	b	x	x	x
assisting and caring	b	x	x	x
counselling	b	x	x	x
providing health care or medical treatments	b	x	x	x
preparing and serving food and drinks	b	x	x	x
providing information and support to the public and clients	b	x	x	x
providing general personal care	b	x	x	x
designing systems and products	b	x	x	x
advising and consulting	b	x	x	x
writing and composing	b	x	x	x
negotiating	b	x	x	x
presenting information	b	x	x	x
working with others	b	x	x	x
teaching and training	b	x	x	x
obtaining information verbally	b	x	x	x
communication, collaboration and creativity	b	x	x	x
using more than one language	b	x	x	x
performing and entertaining	b	x	x	x
liaising and networking	b	x	x	x
promoting, selling and purchasing	b	x	x	x
solving problems	b	x	x	x
creating artistic, visual or instructive materials	b	x	x	x
ESCO Transversal Skills and Competences				
working with numbers and measures	b	x	x	x
working with digital devices and applications	b	x	x	x
processing information, ideas and concepts	b	x	x	x
planning and organising	b	x	x	x
dealing with problems	b	x	x	x
thinking creatively and innovatively	b	x	x	x
working efficiently	b	x	x	x
taking a proactive approach	b	x	x	x
maintaining a positive attitude	b	x	x	x
demonstrating willingness to learn	b	x	x	x
communicating	b	x	x	x
supporting others	b	x		
collaborating in teams and networks	b	x	x	x
leading others	b	x	x	x
following ethical code of conduct	b	x	x	x
manipulating and controlling objects and equipment	b		x	
responding to physical circumstances	b	x	x	x
applying health-related skills and competences	b	x	x	x
applying environmental skills and competences	b	x	x	x
applying civic skills and competences	b	x	x	x
applying cultural skills and competences	b	x	x	x
applying entrepreneurial and financial skills and competences	b	x	x	x
applying general knowledge	b	x	x	x
promoting, selling and purchasing	b	x	x	x
solving problems	b	x	x	x
creating artistic, visual or instructive materials	b	x	x	x

Table 14: Measurement system for latent factors for task content

This is done in order to classify each occupation based on a set of task content using ESCO. For identifying γ^e, I use a set of $m^E \in M^E$ measurements, for $e \in \{S, R, C\}$, where S is for social tasks, R for routine tasks and C for non-routine analytical (cognitive):

$$m_{ij}^E = a_j + \lambda_{ji}\gamma_i^S + \lambda_{ji}\gamma_i^R + \lambda_{ji}\gamma_i^C + \varepsilon_{ij}, \tag{14}$$

where $m^E \in M^E$ is a set of binary outcomes for each skill group. Indeed, m^E identifies if for a given occupation, one of the narrower skills of the broader skill group is cited by the ESCO dictionary as either essential or optional. The three factors obtained are interpreted as social, routine, and cognitive task content for each occupation.

Table 15: Correlation: PCA, EFA and CFA

	PCA Component 1	PCA Component 2	PCA Component 3	Factor 1	Factor 2	Factor 3	Social γ^S	Routine γ^R	Cognitive γ^C
Social γ^S	0.9618	0.0172	0.2403	0.7186	0.0029	0.7023	1		
Routine γ^R	0.0635	0.9494	-0.1906	0.2436	0.9147	-0.2118	0.0309	1	
Cognitive γ^C	0.7935	0.4413	-0.3864	0.9207	0.3556	0.0446	0.6834	0.572	1

In Table 15, I show the correlation between measures extracted by PCA, EFA, and CFA. Essentially, factors interpreted as social is highly correlated with PCA component 1 and with Factor 1, while routine is highly correlated with PCA component 2 and with Factor 2. Regarding, the non-routine analytical (cognitive) factor, it is actually strongly correlated between PCA component 1 and Factor 1, indicating a strong correlation between social and cognitive tasks (as indicated in Deming, 2017).

A.1.2 Alternative Measures for Robustness Checks

As a robustness check, I can classify occupations using a different measure of task content. Other than using PCA or EFA measures for defining occupations, I could use a continuous measure, without relying on factors.

Table 16: Broader Groups and Task Content

Social	**Routine**	**Nonroutine Analytical (Cognitive)**
S1 - communication, collaboration and creativity	S6 - handling and moving	S2 - information skills
S3 - assisting and caring	S7 - constructing	S5 - working with computers
S4 - management skills	S8 - working with machinery and specialised equipment	
T4 - social and communication skills and competences		T1 - core skills and competences
	T5 - physical and manual skills and competences	T2 - thinking skills and competences
		T3 - self-management skills and competences
		T6 - life skills and competences

In Table 16, I use a set of specific broader groups to define a continuous measure of task content, which is based on the number of skill requirements required by each occupation for each of these three set of broader groups.

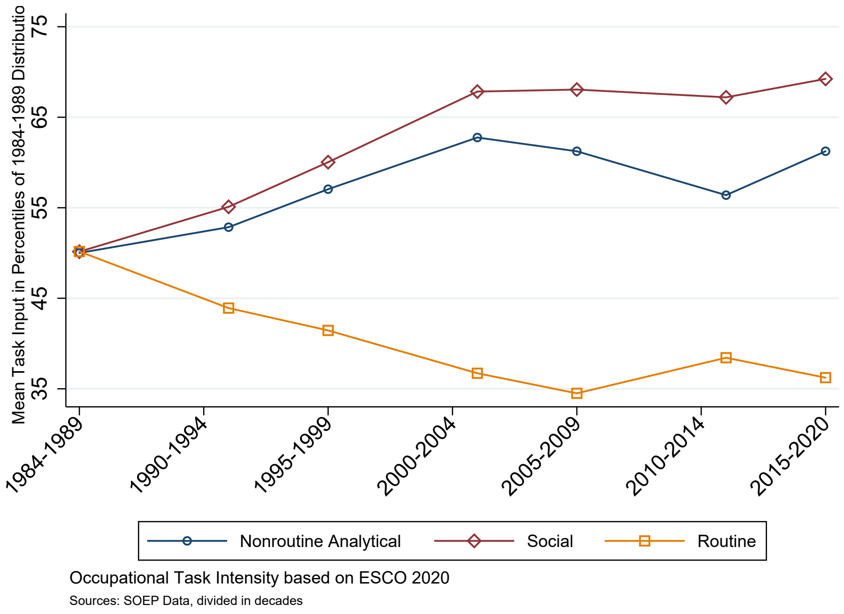
Table 17: Correlation: Factors and Continous Measures

	Social γ^S	Routine γ^R	Cognitive γ^C	Social cont.	Routine cont.	Cognitive cont.
Social cont.	0.9727	0.0142	0.6725	1		
Routine cont.	0.0038	0.903	0.3396	-0.0189	1	
Cognitive cont.	0.8219	0.3099	0.8856	0.7749	0.1411	1

Notes: Social γ^S, Routine γ^R, and Cognitive γ^C denotes the factors extracted using the model, while Social cont., Routine cont., and Cognitive cont. denotes the continuous measures of task content, normalizing the number of narrower skills contained in each occupation.

In Table 17, I show the correlation between factors and continuous measures. Essentially, continuous measures are highly correlated with their respective factors. Again, social and cognitive task measures are highly correlated.

Figure 13: Worker Tasks in Germany, 1984-2020



A.2 GSOEP Appendix

I investigate the changes in wage returns to multidimensional skills using data from Germany. The analysis uses data from the German Socio-Economic Panel data (GSOEP, 2020), which is a longitudinal micro-dataset containing a large number of individuals and households in Germany, and was started in 1984. Presently, the GSOEP includes data on over 20,000 individuals and 10,000 households (see Wagner et al., 2007; Humphries and Kosse, 2017). This dataset is representative and provides a comprehensive range of socio-economic information on individuals and private households in Germany.

The initial data collection began in 1984, with about 12,200 adult respondents randomly selected from West Germany. Following the German reunification in 1990, the GSOEP was expanded to include approximately 4,500 individuals from East Germany, and later, additional samples were added for further supplementation. Beginning in 2000 (for individuals born in 1983), a Youth questionnaire was administered to all young people at the age of 17, which contains specific questions about education and aspirations as they are being interviewed for the first time. From 2006 (for those born in 1989), the questionnaire included a comprehensive set of measures, assessing both cognitive and non-cognitive abilities.[23]

The GSOEP's Youth Questionnaire contains data on 9,370 individuals, which can be complemented with subsequent individual questionnaires. Overall, I have 125,728 individual-year observations for these individuals, which includes data from the household questionnaire (59,188 individual-year observations after the age of 17 and subsequent to the receipt of the Youth questionnaire) and data from the individual surveys conducted after the age of 17. Of the 9,370 individuals, data on potential cognitive performance is available for 4,055 individuals. Thus, I restrict our sample for estimating the model to those individuals for whom I have cognitive test data, resulting in a final sample of 4,055 individuals.

A.2.1 Demographic Cohorts

Potentially, I would estimate the models with time-specific estimates. However, to keep the model tractable and estimate the changes across cohorts, I define two different demographic cohorts: M, those born before 1995 (Millennials, following a definition of demographic cohorts), and Z, those born after 1995 (also known as Generation Z). The main difference between these two demographic cohorts is the different use of ICTs, as explained by PEW research.[24]

From a practical perspective, in Table 18, I show that the year of birth 1995 divides the Youth questionnaire in half, with a cumulative percentage of 52,69% of individuals

[23]To investigate the cognitive performance potential of adolescents, they developed a questionnaire based on the I-S-T 2000 test, which is suitable for an individual panel survey.

[24]See, for instance, Generation Z report by PEW research institute.

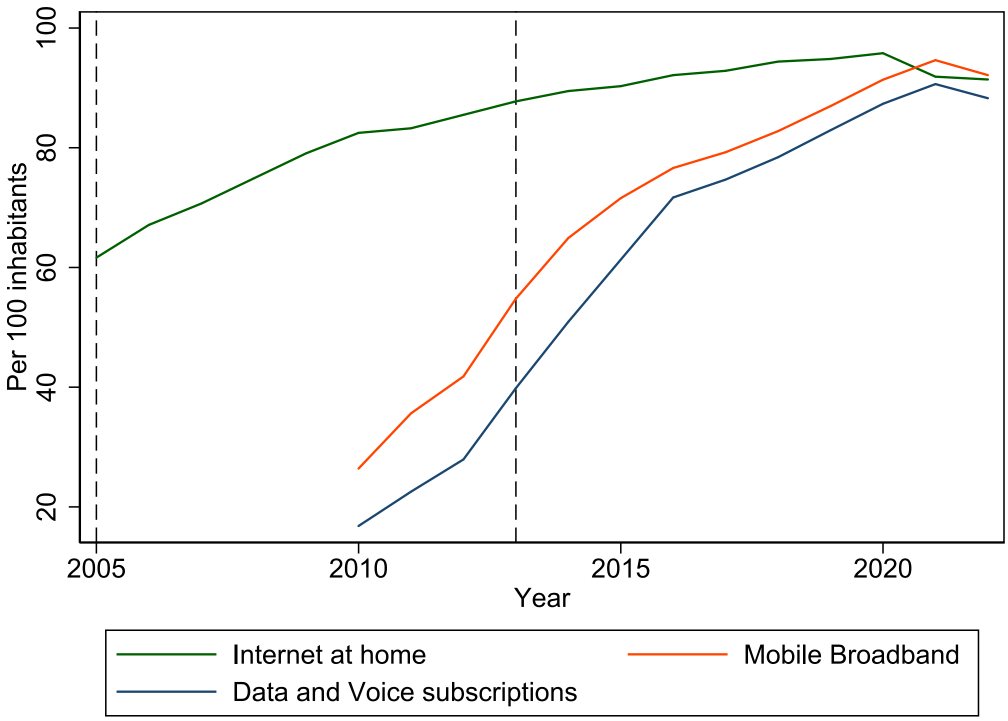


Figure 14: Internet Use across Cohorts (OECD Data)

born before or in 1995.

Table 18: Year of Birth: Youth Questionnaire

Year of Birth	Freq.	Percent	Cum.
...	...	...	...
1993	404	4.31	41.31
1994	531	5.67	46.98
1995	535	5.71	52.69
1996	568	6.06	58.75
1997	578	6.17	64.92
...	...	...	...
Total	9,368	100	

However, as a further robustness check, I also estimate the models removing individuals at the margins of 1995 (including individuals born in 1994 and 1996).

A.2.2 Measurement System for Skills

Using the GSOEP Dataset, I have access to a large set of measures of cognitive and non-cognitive skills. Potentially, it is possible to utilize this extensive list of measures and estimate each individual effect separately. However, it is important to consider that these skill measures are likely to be correlated with one another. Additionally, it is crucial to prioritize parsimony when dealing with such a vast amount of information in measurement. These measures are likely to be measures of underlying common factors.

Therefore, I link the questionnaire on cognitive tests (COGDJ) to the youth questionnaire (JUGENDL).[25] COGDJ includes a set of three different standardized tests, each containing 20 questions. The JUGENDL Questionnaire comprises an extensive range of inquiries, encompassing personal characteristics, time allocation, aspirations, and various other traits. Lastly, this questionnaire also includes school grades and other details about the schooling skill of each individual.[26] Indeed, both contain a large set of measurements aimed at identifying, with measurement error, a limited number of latent factors. Following Deming (2017), Humphries et al. (2019), and Toppeta (2022), I focus on identifying a latent factor for cognitive skills (θ^c), while identifying two latent factors from non-cognitive measurements: in Toppeta (2022), these are referred to as externalizing and internalizing factors. Indeed, The psychometric literature identifies two dimensions of socio-emotional development: internalizing (ability to focus their drive and determination) and externalizing (ability to engage in interpersonal activities) skills (Achenbach, 1966; Goodman, 1997, 2001; Goodman et al., 2010; Achenbach et al., 2016). In line with the literature on returns to skills, following Deming (2017), I refer to them simply as a social skill (θ^{sc}) and a more general non-cognitive skill (θ^{nc}). This latter skill, therefore, is more related to diligence, the ability to focus, to be hard-working, and to work efficiently, without wasting time.

As done with ESCO, I start by analyzing the non-cognitive skills measure using a PCA and a EFA.

In Figure 15, there are at least, 4 components that explain a significant fraction of the variation in non-cognitive measures.

This is also confirmed in Figure 16, where 4 main factors are above the mean.

I use a measurement system with both categorical and continuous variables to measure the latent factors. The measurement system with categorical items exploits the variation from each item - instead of aggregating their responses in continuous subscales to estimate

[25]To measure cognitive skills, the participants took part in a validated short version of the well-established "I-S-T 2000 R"(Amthauer et al., 2001), covering all three subsets which are verbal, numerical, and figural abilities (for details see Solga et al., 2005)

[26]i.e. if the individual enroled in advanced or basic courses in German, Mathematics or Foreign Languages.

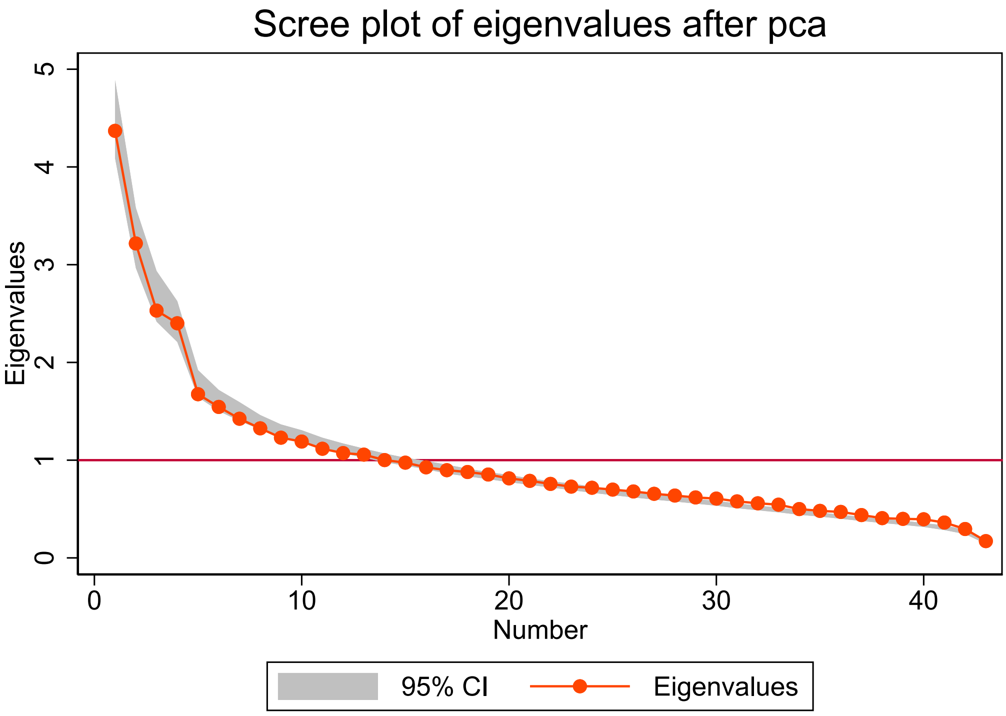


Figure 15: GSOEP PCA Analysis

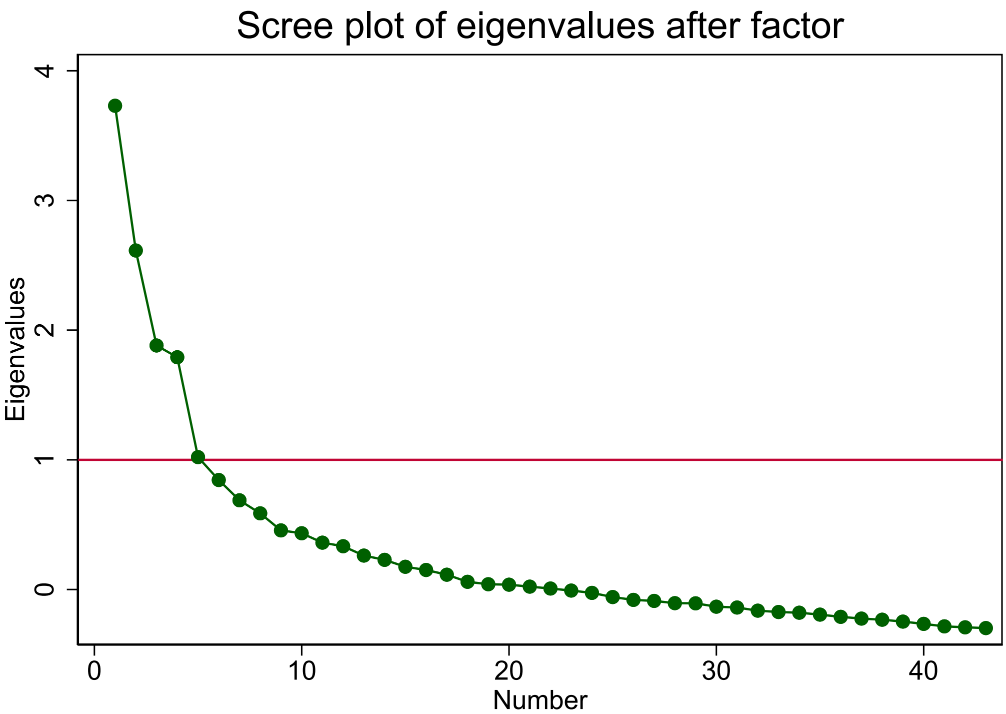


Figure 16: GSOEP EFA Analysis

a factor model with continuous items.[27] As in Humphries and Kosse (2017), I estimate non-cognitive skills from a large set of measurements available in the GSOEP dataset: participation in extracurricular activities (including competition in sports), time allocation to a set of activities, satisfaction with school achievements, self-reported probability of future success, risk preference, time preference, trust measures, personal characteristics (Big 5), political interest, locus of control and amount of closed friends. The full list is included in Table 19. In comparison to Humphries et al. (2019), I interpret these factors as skills rather than abilities. This interpretation is based on the fact that these measures were obtained at the age of 17, suggesting a developmental aspect influenced by external factors, rather than being solely innate or predetermined abilities. Moreover, I do not include exogenous and schooling-specific characteristics. In this paper, skills are defined as endogenous, meaning they can be acquired and improved through learning and practice, while abilities are considered inherent or exogenous traits. In my analysis employing a dynamic treatment effect approach, I incorporate the notion of ability through the utilization of finite mixtures and an exogenous number of unobserved types. These unobserved types are assumed to possess distinct developmental traits and employ a set of skills in different ways (refer to the Section 3 for more details).[28]

Using a large set of cognitive standardized tests, academic performances, and non-cognitive measures, I identify three latent factors: θ^c, θ^{nc} and θ^{sc}. These factors are underlying skills, measured with an error by the GSOEP dataset questionnaires and they are related to, respectively: cognitive, non-cognitive, and social skills. As mentioned before, I utilize a set of measurements for identifying θ^c, while I identify the two measurements θ^{nc} and θ^{sc} using the same set of measurements and, therefore, these are two ability identified using the same measurement system. In this case, non-cognitive skills are conditional on social skills.

The set of measurements is consistently large for each of these measures. I use a non-linear factor model to identify these factors using a comprehensive and large set of measures. For identifying θ^c, I use a set of $m^c \in M^c$ dedicated measurements:

[27] Cunha et al. (2010), Agostinelli et al. (2020), Attanasio, Blundell, et al. (2020), and Attanasio, Cattan, et al. (2020) employ a measurement approach that utilizes continuous items and focuses on a limited number of human capital dimensions. Specifically, they examine a single aspect of socio-emotional development, rather than considering the two distinct dimensions of socio-emotional skills, namely internalizing and externalizing.

[28] e.g. Individuals may differ in the productivity of having both high measures of cognitive and non-cognitive.

$$m_{ij}^{c} = a_j + \lambda_{ji}\theta_i^c + \varepsilon_{ij} \tag{15}$$

Regarding non-cognitive skills, I identify 2 factors from a set of measurements $m^{nc} \in M^{nc}$:

$$m_{ij}^{nc} = a_j + \lambda_{ji}^1\theta_i^d + \lambda_{ji}^2\theta_i^s + \varepsilon_{ij} \tag{16}$$

Based on this estimation, I interpret θ^{nc1} as a general measure of non-cognitive abilities, θ^{nc}, such as grit, hard-working, conscientiousness, patient, while I interpret θ^{nc2} as θ^{sc}, as a measure of non-cognitive skills linked to sociability, extroversion, leadership and other skills linked to higher interactions. Of course, individuals may have high skills in both of these factors. This could be referred to as an externalizing and an internalizing factor (Toppeta, 2022).

Table 19 contains the full measurement system for the latent factors. It consists of 75 measures for the cognitive factor θ^c, and of 76 measures for extracting two non-cognitive factors θ^d and θ^s.[29] I include a set of parental involvement measures for identifying the cognitive factor because of two main reasons: (i) an individual may display a larger cognitive skill and, therefore, parents may be more willing to help him develop her skills and (ii) more involved parents may be a proxy for early schooling investments with high returns on cognitive skills at the age of 17.

Figure 17 illustrates the relationship between three multidimensional skills. It reveals that individuals with high cognitive skills but low diligence skills tend to exhibit higher social skills. Notably, social and diligence skills represent distinct dimensions of skills, and individuals may focus on developing one dimension more than the other.

Table 19: Measurement system for latent factors θ^c, θ^{nc} and θ^{sc}

Measures		θ^c	θ^d	θ^s
Data on cognitive tests (COGDJ)				
20 Analogies questions	*b*	x		

[29]Measures highlighted in italics are chosen to be reference measures for identifying the latent factors. Respectively: Grade Mathematics for θ^c, personal characteristics: work carefully for θ^{nc} and personal characteristics: communicative for θ^{sc}. The normalization of the factor loadings to 1 and choosing dedicated measures are crucial for identifying these factors.

20 Arithemtic Operator questions	*b*	x		
20 Figures questions	*b*	x		

Youth Questionnaire (JUGENDL)

Grade German	*c*	x		
Grade Mathematics	*c*	x		
Grade 1. Foreign Langauge	*c*	x		
Advanced Course German	*b*	x		
Advanced Course Mathematics	*b*	x		
Advanced Course 1. Foreign Langauge	*b*	x		
Support tutor	*b*	x		
Abitur preferred certificate	*b*	x		
Parents Show Interest In Performance	*b*	x		
Parents Help With Studying	*b*	x		
Disagreements With Parents Over Studies	*b*	x		
Parents Take Part In Parents-Evening	*b*	x		
Parents Come To Teacher Office Hours	*b*	x		
Parents Visit Teacher Outside Office Hrs.	*b*	x		
Involved As Parents Representative	*b*	x		
Class Representative	*b*		x	x
Student Body President	*b*		x	x
Involved With School Newspaper	*b*		x	x
Belong To Theatre, Dance Group	*b*		x	x
Belong To Choir, Orchestra, Music Group	*b*		x	x
Belong To Volunteer Sport Group	*b*		x	x
Other Kind Of School Group	*b*		x	x
Musical Lessons Outside Of School	*b*		x	x
Musically Active	*b*		x	x
Sport Activity	*b*		x	x
Take Part In Competitions In This Sport	*b*		x	x
How Often Listen To Music	*c*		x	x
How Often Play Music Or Sing	*c*		x	x
How Often Do Sports	*c*		x	x
How Often Dance Or Act	*c*		x	x
How Often Do Tech. Activities	*c*		x	x
How Often Read	*c*		x	x
How Often Spend Time Steady Boy-,Girlfriend	*c*		x	x
How Often Spend Time Best Friend	*c*		x	x

How Often Spend Time Clique	*c*	x	x
How Often Youth Centre, Community Centre	*c*	x	x
How Often Do Volunteer Work	*c*	x	x
Frequency of time in church, attending religious events	*c*	x	x
Satisfaction With Overall School Grades	*c*	x	x
Satisfaction With German Grades	*c*	x	x
Satisfaction With Mathematics Grades	*c*	x	x
Satisfaction With Main Foreign Langauge	*c*	x	x
Probability in %: favoured apprenticeship or university place	*c*	x	x
Probability in %: apprenticeship or university place	*c*	x	x
Probability in %: workplace	*c*	x	x
Probability in %: job success	*c*	x	x
Probability in %: unemployed	*c*	x	x
Probability in %: limitation family	*c*	x	x
Probability in %: self employed	*c*	x	x
Probability in %: job abroad	*c*	x	x
Probability in %: marriage	*c*	x	x
Probability in %: partnership	*c*	x	x
Probability in %: one child	*c*	x	x
Probability in %: more than one child	*c*	x	x
Willingness to take risks	*c*	x	x
Trust People	*c*	x	x
Cannot rely on people	*c*	x	x
Distrust Strangers	*c*	x	x
Have fun today, not think about tomorrow	*c*	x	x
Big 5 Personality traits		x	x
Personal characteristics: work carefully	*c*	x	
Personal characteristics: communicative	*c*		x
Personal characteristics: abrasive towards others	*c*	x	x
Personal characteristics: introduce new ideas	*c*	x	x
Personal characteristics: often worry	*c*	x	x
Personal characteristics: can forgive others	*c*	x	x
Personal characteristics: am lazy	*c*	x	x
Personal characteristics: am outgoing/sociable	*c*	x	x
Personal characteristics: importance of esthetics	*c*	x	x
Personal characteristics: am nervous	*c*	x	x
Personal characteristics: carryout duties efficiently	*c*	x	x
Personal characteristics: reserved	*c*	x	x

Personal characteristics: considerate, friendly	*c*	x	x
Personal characteristics: lively imagination	*c*	x	x
Personal characteristics: be relaxed, no stress	*c*	x	x
Personal characteristics: hunger for knowledge, curious	*c*	x	x
		x	x
Frequency of Being Angry in the Last 4 Weeks	*c*	x	x
Frequency of Being Worried in the Last 4 Weeks	*c*	x	x
Frequency of Being Happy in the Last 4 Weeks	*c*	x	x
Frequency of Being Sad in the Last 4 Weeks	*c*	x	x
Political Interests		x	x
Locus of control		x	x
How my life goes depends on me	*c*	x	x
Compared to other people, I have not achieved what I deserve	*c*	x	x
What a person achieves in life is above all a question of fate or luck	*c*	x	x
I frequently have the experience that other people have a controlling influence over my life	*c*	x	x
You have to work hard to succeed	*c*	x	x
When I run up against difficulties in life, I often doubt my own abilities	*c*	x	x
The opportunities that I have in life are determined by social conditions	*c*	x	x
Innate abilities are more important than any efforts one can make	*c*	x	x
I have little control over the things that happen in my life	*c*	x	x
If a person is socially or politically active, he/she can have an effect on social conditions	*c*	x	x
Amount Of Closed Friends	*c*	x	x

The latent factors are measures of the following skills, selecting the personal characteristics survey questions, used for extracting the Big 5.[30]

In Table 21, I show the correlation between the measures of non-cognitive and social

[30]Note that I refer to skills as these are measures at the age of 17 and they are endogenously determined by the human capital formation process.

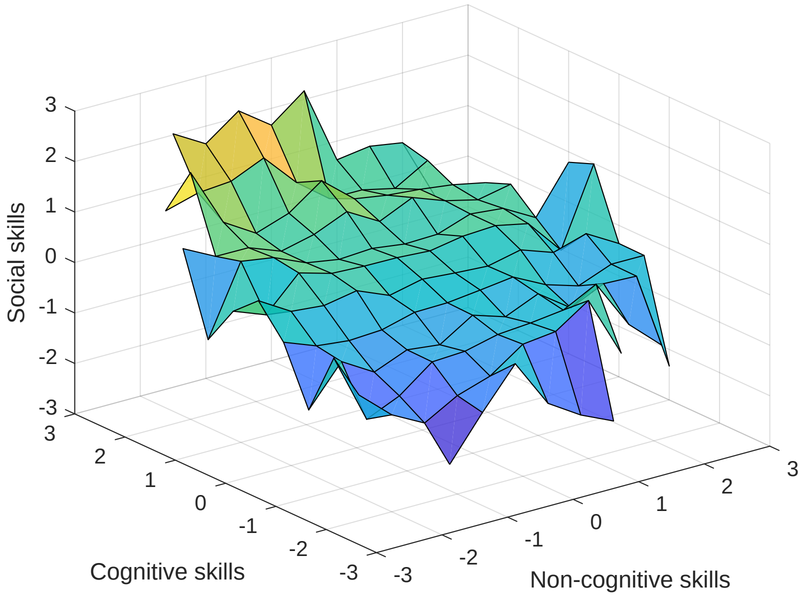


Figure 17: Relationship between Skills

Notes: details on the latent factors used in this Figure are included in A.2 in the Appendix. Latent factors θ are standardized to be mean 0 and standard deviation 1.

Table 20: Interpretation of Latent Factors

Big 5 questions:	θ^c	θ^d	θ^s
Personal characteristics: work carefully	-0.003	**0.742**	0.192
Personal characteristics: communicative	-0.031	0.223	**0.814**
Personal characteristics: abrasive towards others	-0.043	-0.307	0.139
Personal characteristics: introduce new ideas	0.004	0.268	0.563
Personal characteristics: often worry	-0.037	-0.011	0.044
Personal characteristics: can forgive others	0.056	0.274	0.233
Personal characteristics: am lazy	0.083	**-0.526**	**-0.028**
Personal characteristics: am outgoing/sociable	-0.004	**0.158**	**0.843**
Personal characteristics: importance of esthetics	0.097	0.200	0.252
Personal characteristics: am nervous	-0.021	-0.128	-0.243
Personal characteristics: carryout duties efficiently	0.092	**0.759**	**0.284**
Personal characteristics: reserved	0.018	**0.061**	**-0.598**
Personal characteristics: considerate, friendly	-0.026	0.506	0.253
Personal characteristics: lively imagination	0.062	0.110	0.312
Personal characteristics: be relaxed, no stress	0.046	0.321	0.292
Personal characteristics: hunger for knowledge, curious	0.205	0.453	0.278

skills with the PCA and EFA measures.

Table 21: Correlation: PCA, EFA and CFA

	PCA Comp. 1	PCA Comp. 2	PCA Comp. 3	PCA Comp. 4	Factor 1	Factor 2	Factor 3	Factor 4
Diligence skills θ^d	0.7425	0.117	-0.6063	0.1928	-0.3365	0.1233	0.1769	0.9278
Social skills θ^s	0.7939	0.2586	0.4881	0.0976	-0.1801	0.9437	0.2263	0.2

Essentially, my latent factors are strongly correlated with factor 2 and factor 4, respectively. Regarding PCA, it seems they essentially capture component 3.

In the first step, I identify each of these 3 models, while, in the second step, I include these latent skills into a dynamic model of human capital accumulation, considering them as endogenous to prior educational choices. Table 22 presents the correlations between the measures. It shows that social and non-cognitive skills exhibit a correlation of 0.35, whereas cognitive skills have a correlation of 0.05 with social skills and 0.13 with non-cognitive skills.

Figure 18: Distribution of skills across cohorts

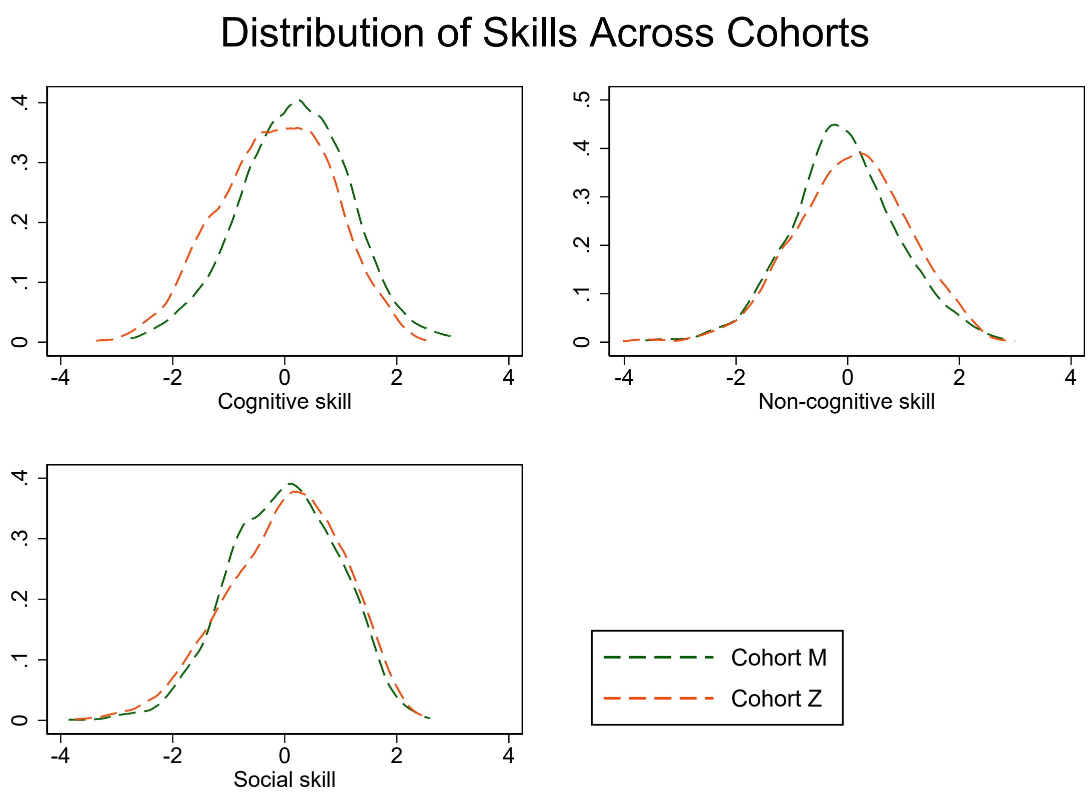


Table 22: Correlation across skill factors

	θ^c	θ^d	θ^s
θ^c	1		
θ^d	0.1331	1	
θ^s	0.0535	0.3505	1

B Model

B.1 Expectation-Maximization Algorithm

In this setting, I estimate the model using the EM algorithm. If we knew the probability types, the likelihood of the model would be completely separable and we could estimate the entire model in stages. However, since these are unobserved to the econometrician, the estimation of this model is done by using an Expectation-Maximization (EM) algorithm (Arcidiacono and Jones, 2003). This method was originally developed by Dempster et al. (1977), and applied to DDC models by, amongst others, Arcidiacono (2004), Arcidiacono and Ellickson (2011), and Arcidiacono and Miller (2011). This method is composed of (i) an expectation and (ii) a maximization step. These two steps are repeated until convergence is achieved.

In the expectation step, we compute the probability of each individual being in each heterogeneity type k, based on the likelihood value for each $k \in K$: $\mathcal{L}_i$. Indeed, for each type k, we know the type-specific likelihood and the total expected likelihood weighted by the probability of being in each type k, $\pi_{k,i}$:

$$\mathcal{L}_i = \sum_{i=1}^{I} \left[\sum_{k=1}^{K} \pi_k \log \left(\prod_{t=1}^{T} \ell_{it}(\gamma_k) \right) \right], \tag{17}$$

Bayes' rule implies that the probability for individual i of being a type k, conditional on the observed variables, endogenous outcomes and unobservables, is:

$$\hat{p}_{mi} = \frac{\pi_{mi}\mathcal{L}_i}{\sum_{m=1}^{M} \pi_{mi}\mathcal{L}_i} \tag{18}$$

In the maximization step, the conditional probabilities of being heterogeneity type m are treated as given, which allows us to optimize the full model by maximum likelihood. Note that, as Arcidiacono and Jones (2003) show, the maximization step can be now carried out in stages: indeed, once we treat the heterogeneity probabilities as given, the likelihood is again fully separable, as mentioned at the beginning of this section.

$$\mathcal{L}_i = \sum_{i=1}^{I} \left[\sum_{m=1}^{M} \hat{p}_{mi} \log \left(\prod_{t=1}^{T} \ell_{it}(\gamma_m) \right) \right], \tag{19}$$

After the maximization step, we update the conditional probabilities and iterate to the next maximization. This process is repeated until convergence is obtained. To identify the optimal number of heterogeneity types m, we re-estimate the model by gradually adding up to four types to the model. Moreover, as the model does not have a global solution, we need to re-estimate the model multiple times and select the best-fitting model.

B.2 Model Selection

In Table 23, I include the log-likelihood for each model by cohort and number of unobserved types, using different starting values.

Table 23: Model Selection

		Seed (random starting values)				
Cohort:	Number of heterogeneity types:	1	2	3	4	5
M	2	16483.474	16554.381	16554.646	16555.323	16554.629
	3	16114.014	**16075.457**	16075.469	16075.467	16075.475
	4	15755.739	15897.254	15697.410	15747.197	15754.570
Z	2	14416.782	14449.712	14449.773	14449.781	14449.855
	3	14838.979	14687.862	**14805.691**	14687.853	14838.975
	4	15085.964	15207.404	15086.003	15086.002	15207.405

Based on these values, I select the model with 3 heterogeneity types in both cohorts for two main reasons: (i) to keep consistency across cohorts and (ii) as for cohort Z, the model with 4 heterogeneity types does not converge correctly.

B.3 Treatment Effects

I begin with representing log-hourly starting wages $\log(\text{wage})_i$ as a function of individual characteristics, X, and observed skills, θ^j:

$$\log(\text{wage})_i = f_m\left(X_i, \theta_i^j\right) \tag{20}$$

In this context, the wage return to skills can be calculated simply as $\frac{d\log(\text{wage})}{d\theta^j} = \frac{df_m\left(X_i,\theta_i^j\right)}{d\theta^j}$: this is the total wage return to skills, after controlling for individual characteristics. As I am considering starting wages, I do not include in this analysis the role of prior work experience (as in Ashworth et al., 2021).

I introduce two additional elements: (i) as skills are usually measured at the end of secondary schooling (i.e. between the age of 17 and 18, depending on the dataset and the country), they are endogenously determined by schooling choices, f^s and (ii) skills impact tertiary education, f^e.[31] Therefore, this would be a stylized, yet more detailed equation of wages, relative to Equation 20:

$$\log(\text{wage}) = f\left(X, f^s, \theta^j, f^e\right) \tag{21}$$

Now, the returns to skills can be computed as:

$$\underbrace{\frac{d\log(\text{wage})}{d\theta^j}}_{\text{Total effect}} = \underbrace{\frac{\partial\log(\text{wage})}{\partial\theta^j}}_{\text{Direct effect}} + \underbrace{\frac{df^e}{d\theta^j}\frac{\partial\log(\text{wage})}{\partial f^e}}_{\text{Indirect effect}} \tag{22}$$

where the total effect is decomposed into a direct and indirect component of the impact of skills on wages. Undoubtedly, skills significantly influence tertiary education, which in turn has a consequential effect on wages. This framework provides a simple yet powerful approach applicable to diverse contexts in labor and education economics. It can be readily implemented using dynamic treatment effects models, enabling the estimation of treatment effects by considering counterfactual scenarios.

B.4 Counterfactual Simulation

To assess the treatment effects and establish confidence intervals, we employ a counterfactual simulation strategy (Cockx et al., 2019). In this approach, we conduct 999 simulations, randomly drawing parameters from the asymptotic normal distribution of the model's parameters. Subsequently, for each simulation draw, we utilize the probability types estimated through the EM algorithm to assign a heterogeneity type to each individual in the sample randomly. Based on these newly generated parameters, we simulate the complete sequence of schooling and labor market outcomes for each individual. We also employ this counterfactual simulation strategy to evaluate the model's quality

[31] Schooling choices f^s are determined by individual observed characteristics. While skills, θ^j, are endogenously determined by both observed characteristics and schooling choices. Tertiary education, f^e, is also influenced by individual observed characteristics, schooling choices, and skills.

by generating a comprehensive set of outcomes and comparing them to the observed outcomes in the data. This evaluation is presented in Section B.5. In most cases, the observed probabilities fall within the 95% confidence bounds of the simulated probabilities, indicating a good fit of the model to the observed outcomes in the dataset.

B.5 Goodness of fit tables

Table 24: Goodness of Fit - Models Demographic Cohorts

	M ((1987-1995)					Z (1996-2003)				
	Observed	Simulated	SE	95 CI		**Observed**	Simulated	SE	95 CI	
Grade Repetition (Primary Education)	**0.069**	0.072	0.008	0.056	0.087	**0.091**	0.094	0.010	0.073	0.114
School Recommendations	**2.926**	2.965	0.030	2.906	3.023	**2.617**	2.624	0.036	2.553	2.695
Grade Repetition (Secondary Education)	**0.148**	0.152	0.011	0.130	0.174	**0.148**	0.155	0.013	0.130	0.180
Secondary Education Enrollment	**2.226**	2.236	0.017	2.203	2.270	**2.244**	2.256	0.021	2.215	2.297
Cognitive Skills	**0.170**	0.174	0.021	0.132	0.216	**-0.191**	-0.193	0.025	-0.242	-0.144
Non-cognitive Skills	**-0.054**	-0.049	0.020	-0.088	-0.010	**0.060**	0.050	0.023	0.006	0.094
Social Skills	**-0.001**	0.007	0.021	-0.035	0.049	**0.001**	-0.006	0.024	-0.054	0.041
Secondary Education Diploma	**2.999**	3.044	0.024	2.997	3.091	**2.736**	2.776	0.031	2.714	2.838
Tertiary Education Enrollment	**0.575**	0.576	0.016	0.545	0.608	**0.329**	0.324	0.018	0.288	0.361
Tertiary Education Diploma	**0.759**	0.761	0.019	0.723	0.799	**0.443**	0.469	0.035	0.401	0.537
Wage Selection	**0.697**	0.700	0.015	0.671	0.730	**0.540**	0.546	0.018	0.510	0.581
Starting log hourly wages	**1.679**	1.680	0.021	1.639	1.721	**1.687**	1.693	0.028	1.639	1.748

Table 25: Distribution of Changes Across Cohorts by Skill Bundle

		$\theta^s > 0$				$\theta^s < 0$			
		M		Z		M		Z	
		Direct	Total	Direct	Total	Direct	Total	Direct	Total
$\theta^c > 0$	Skills	0.065	0.006	0.202**	0.144*	0.168***	0.103*	0.207**	0.145
		(0.056)	(0.050)	(0.081)	(0.082)	(0.060)	(0.056)	(0.093)	(0.090)
	Cognitive skills θ^c	0.096***	0.033	0.053	0.015	0.122***	0.066**	0.125***	0.088**
		(0.034)	(0.022)	(0.045)	(0.039)	(0.031)	(0.027)	(0.048)	(0.035)
	Diligence skills θ^d	0.011	-0.004	0.051	0.027	0.069**	0.052**	0.017	-0.005
		(0.036)	(0.021)	(0.043)	(0.036)	(0.035)	(0.026)	(0.050)	(0.040)
	Social skills θ^s	-0.002	0.014	0.085**	0.073**	0.010	0.023	0.045	0.034
		(0.034)	(0.022)	(0.042)	(0.036)	(0.034)	(0.026)	(0.045)	(0.035)
$\theta^c < 0$	Skills	0.034	-0.015	0.174***	0.108*	0.174***	0.107**	0.177**	0.112
		(0.054)	(0.048)	(0.048)	(0.055)	(0.061)	(0.047)	(0.069)	(0.074)
	Cognitive skills θ^c	0.080**	0.014	0.057	0.024	0.122***	0.058**	0.131***	0.099**
		(0.035)	(0.026)	(0.037)	(0.035)	(0.042)	(0.027)	(0.042)	(0.039)
	Diligence skills θ^d	-0.003	-0.008	0.004	-0.022	0.068	0.053**	-0.026	-0.051
		(0.034)	(0.025)	(0.034)	(0.031)	(0.046)	(0.026)	(0.043)	(0.040)
	Social skills θ^s	-0.010	0.017	0.087**	0.078**	0.013	0.033	0.043	0.034
		(0.037)	(0.029)	(0.036)	(0.033)	(0.042)	(0.028)	(0.042)	(0.038)

Notes: This graph includes the treatment effects of a σ increase to each skill by different skill bundles.

C Results

C.1 Changes in Complementarities

C.2 Model without Unobserved Heterogeneity

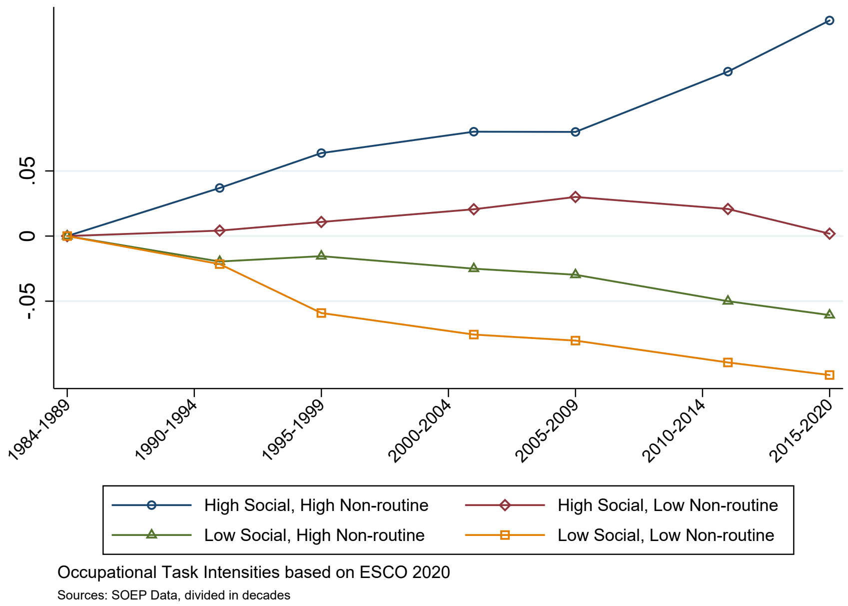
Table 26: Model accounting for unobserved heterogeneity

	M (1987-1995)				Z (1996-2003)			
	Without accounting for unobserved heterogeneity		Unobserved heterogeneity		Without accounting for unobserved heterogeneity		Unobserved heterogeneity	
	Total	Direct	Total	Direct	Total	Direct	Total	Direct
Skills	0.147***	0.052	0.112**	0.052	0.214***	0.170***	0.187***	0.123*
	(0.041)	(0.039)	(0.046)	(0.044)	(0.053)	(0.053)	(0.057)	(0.063)
Cognitive skills (θ^c)	0.105***	0.036*	0.105***	0.044**	0.097***	0.060**	0.090***	0.055*
	(0.023)	(0.021)	(0.022)	(0.020)	(0.029)	(0.029)	(0.030)	(0.030)
Diligence skills (θ^d)	0.042	0.014	0.038	0.025	0.004	-0.004	0.007	-0.017
	(0.026)	(0.019)	(0.023)	(0.018)	(0.030)	(0.026)	(0.029)	(0.028)
Social skills (θ^s)	0.001	0.004	0.002	0.021	0.069***	0.065***	0.066**	0.056**
	(0.025)	(0.018)	(0.025)	(0.020)	(0.025)	(0.023)	(0.029)	(0.027)
$\theta^c\theta^d$	-0.003	-0.009	-0.026	-0.031	0.047	0.050*	0.030	0.033
	(0.030)	(0.021)	(0.024)	(0.020)	(0.032)	(0.028)	(0.031)	(0.029)
$\theta^c\theta^s$	0.003	0.007	-0.007	-0.006	-0.002	0.001	-0.006	-0.005
	(0.029)	(0.023)	(0.027)	(0.022)	(0.029)	(0.028)	(0.029)	(0.026)

D Robustness Checks

D.1 Task Content without Latent Factors

Figure 19: Relative Changes in Employment Share by Occupation Task Intensity



D.2 Changes in Present Value Earnings to Skills

Table 27: Results using Average Present Value for Earnings

	(1) M		(2) Z		(2)-(1) Change	
	Direct	Total	Direct	Total	Direct	Total
Skills	0.114*	0.119	0.182*	0.186*	0.068	0.067
	(0.064)	(0.073)	(0.104)	(0.104)	(0.076)	(0.072)
Cognitive skills (θ^c)	0.057**	0.053*	0.075	0.088	0.018	0.035
	(0.029)	(0.030)	(0.056)	(0.058)	(0.043)	(0.038)
Diligence skills (θ^d)	0.011	0.015	0.017	0.014	0.005	-0.002
	(0.029)	(0.028)	(0.060)	(0.060)	(0.051)	(0.047)
Social skills (θ^s)	-0.011	-0.004	0.065	0.066	0.076	0.070
	(0.035)	(0.031)	(0.063)	(0.061)	(0.050)	(0.046)

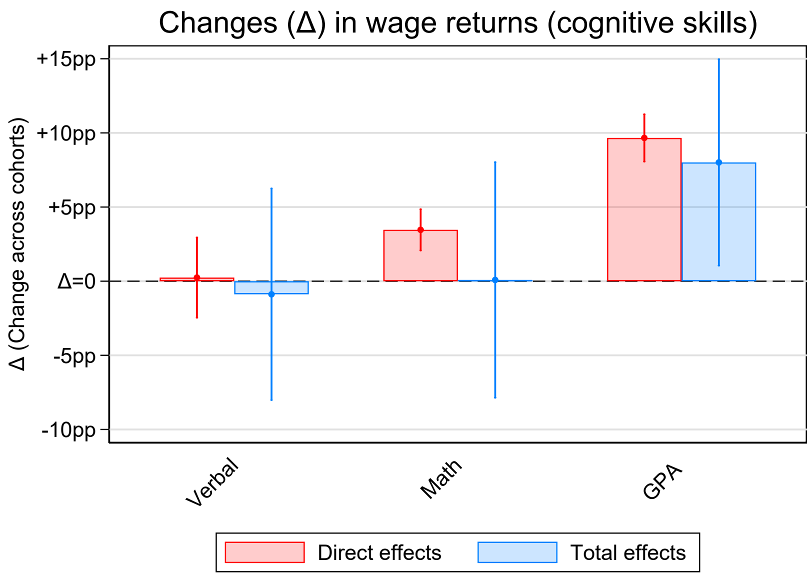
Table 28: Changes in Returns to Multidimensional Skills Across Cohorts

	(1) M		(2) Z		Changes in returns (2)-(1)	
	Direct	Total	Direct	Total	Direct	Total
Cognitive skills	0.036	0.121***	0.170***	0.194***	0.134***	0.073**
	(0.036)	(0.046)	(0.050)	(0.050)	(0.018)	(0.036)
Non-cognitive skills	0.030	0.006	0.095	0.151	0.064	0.146**
	(0.079)	(0.090)	(0.104)	(0.106)	(0.041)	(0.057)

Notes: I estimate the effect of a σ increase in all measures aggregated into broader measures of cognitive (including standardized tests and GPA) and non-cognitive skills (including the Big 5 personality traits, confidence, risk and time preferences).

D.3 Changes in Returns to Multidimensional Skills

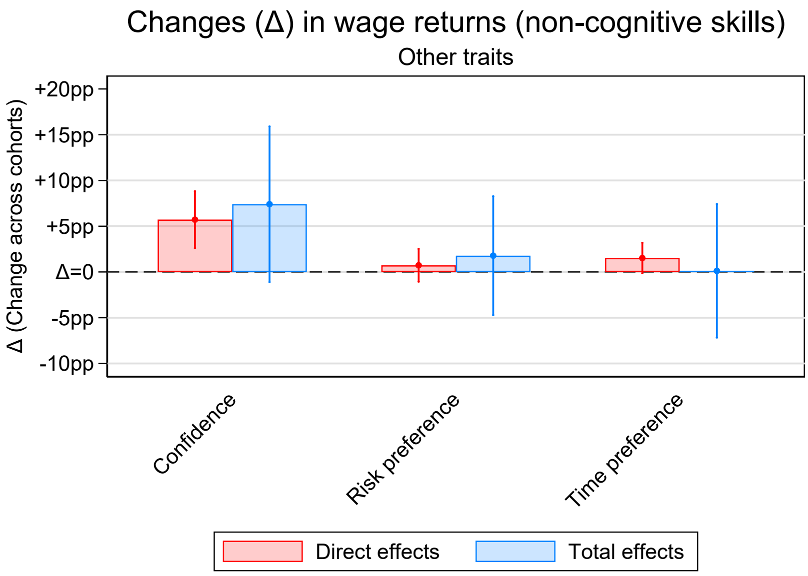
Figure 20: Changes in Wage Returns



Notes: Change, Δ_a^g, in wage returns across cohorts expressed in percentage points (p.p.). The change is the difference between cohort Z and M in the wage return to a σ increase in each specific skill. Direct effects do not include the indirect effects of education. Total effects include the composite effect of direct and indirect effects of a σ increase.

Figure 21 displays the additional non-cognitive skills considered in the analysis: confidence, risk preference, and time preference. Notably, there is a significant change in returns associated with confidence. Confidence is, again, one of the main predictor of social skills, validating my results.

Figure 21: Changes in Wage Returns



Notes: Change, Δ_a^g, in wage returns across cohorts expressed in percentage points (p.p.). The change is the difference between cohort Z and M in the wage return to a σ increase in each specific skill. Direct effects do not include the indirect effects of education. Total effects include the composite effect of direct and indirect effects of a σ increase.