Training Regimes and Skill Formation in France and Germany: An Analysis of Change between 1970 and 2010

Benjamin Elbers*
Department of Sociology, Columbia University

Thijs Bol
Department of Sociology, University of Amsterdam

Thomas A. DiPrete
Department of Sociology, Columbia University

Abstract

Stratification research has long been interested in the distinction between vocational and general education, which led to an influential ideal-type classification of educational systems as "qualificational spaces"—exemplified by Germany—or "organizational spaces"—exemplified by France. Ironically, while the theoretical emphasis has been on the asserted greater strength of linkage between vocational credentials and occupational outcomes, explicit attention to the issue of whether vocational programs are actually successful at providing close linkage to labor markets has been rare. To rectify this omission, we measure the (possibly changing) strength of education-occupation linkage in France and Germany between 1970 and 2010. We find that the structural differences between the skill formation systems of the two countries were much smaller than suggested suggested in the literature, which calls into question the validity of the qualificational-organizational space distinction. Our results underscore the importance of attending to structural as well as compositional differences in educational systems across countries and over time. They also raise the question whether the standard classifications of skill formation systems need to be revisited.

1 Introduction

Social scientists have a longstanding interest in how educational systems prepare workers for the labor market.[1] Theoretical depictions of skill formation systems rely on ideal types,

*be2239@columbia.edu

[1]This study is based on data from Eurostat, European Labor Force Survey, and other data sources. The responsibility for all conclusions drawn from the data lies entirely with the authors.

and often separate vocational systems, where work and study are combined, from general systems, where education remains largely school-based and skill acquisition is more general (e.g., Shavit and Müller 1998). A large body of literature has used this distinction, trying to explain cross-national variation in youth unemployment, occupational mobility, status of the first job, or the length of job search (e.g., Breen 2005; Bol and Van de Werfhorst 2013), among other topics.

One of the most influential studies in the school-to-work literature is Maurice, Sellier, and Silvestre's trailblazing book "The Social Foundations of Industrial Power" (1986). Their in-depth comparison of the French and German skill formation systems formed the fundament of most classifications that are still in use. Maurice et al. argue that the French and German skill formation regimes have radically different approaches to organizing the match between schools and labor markets. France is characterized by an *organizational space*, where workers are hired based on their level of general education. Germany, in contrast, is described as a *qualificational space*, where jobs are closely matched to workers with specific qualifications that they obtained within the educational system. The findings of this study have been integrated in a thorough and well-established literature in sociology, political science, and economics concerning the importance of educational systems for stratification outcomes.

In this literature, France and Germany have become the paradigms of the organizational-qualification space distinction. These countries were the prime examples used by Shavit and Müller to rebut what they referred to as the national similarities model coming (for different reasons) from neo-institutionalist theory (Meyer, Ramirez, and Soysal 1992; Meyer 1980; Benavot et al. 1991) and from the theory of industrialism (Treiman 1970). Neo-institutionalists argued that the "increasing dominance of standardized models of education" were behind a decline in the emphasis in national educational systems on secondary vocational education as part of a "growing global ideology, egalitarian in character, that shuns formal differentiation of children while they occupy the status of high school pupil" in favor of comprehensive high school systems (Benavot 1983). Shavit and Müller, in contrast, argued that empirical analysis shows continuing differences that are consistent with the "qualificational" and "organizational" distinction proposed by Maurice et al.

Shavit and Müller's conclusion, however, has been called into question by recent developments. First, DiPrete et al. (2017) found that France and Germany differ less than expected in terms of how closely educational pathways and the occupational distribution are linked. Second, DiPrete et al. (2017) focused attention on an important dimension of educational systems that was understudied in the CASMIN project, namely the extent to which specific educational credentials, including different fields of study, tracked graduates into specific occupational careers. The authors found that the French skill formation system often performs equally well in terms of leading graduates to a similar set of specific occupations as the German qualificational space. Their analysis illuminated the fact that educational systems can differ on a "structural" dimension—the strength of linkage—as well as on a compositional dimension (the distribution of students across the available educational tracks) that is inherent in the CASMIN approach.

In combination with the finding of greater similarity between Germany and France than predicted, the approach of DiPrete et al. calls attention to the question of the nature of change over time. Were France and Germany always as similar as they are now? If either or both countries changed, what was the nature of the change? Was it largely a change in

the composition of school leavers who were in a vocational or academic track? Or were the changes also of a structural nature, meaning that educational tracks (whether vocational or academic) were becoming more (or less) closely tied to specific occupations? The questions are important not only because they provide a new lens for examining the original findings of Maurice et al. and the more recent findings from Shavit and Müller's comparative project, but also because they provide a template for examining change in a country's skill formation system system.

2 Country-level ideal types

Three questions have implicitly or explicitly framed the comparative education literature arguing for the centrality of national differences. The first question concerns the nature of the difference between alternative educational systems. The second question concerns whether and how these systems change. The third question concerns the consequences of alternative educational systems for labor market outcomes at both a micro and a macro level. These question have been usually formulated at the country-level.

First, Müller and Shavit argued that the key structural difference across alternative systems concerned *rates* of vocational education and their implications for the pathways that lead from school to work:

> In sum then, we distinguish between two ideal-typical regimes of school-to-work transitions, which, following Maurice, Sellier, and Silvestre, we label *qualificational* and *organizational spaces*. The qualificational space is characterized by a high rate of *specific vocational education*. More precisely, a large proportion of the graduating cohorts leave the educational system with specific skills and occupational identities. This is in contrast with organizational spaces where education is predominantly *academic* or *general*, and where occupational skills are learnt on the job or in courses taken after leaving school. (Müller and Shavit 1998, p. 9)

This focus on the importance of rates of vocational or general education within countries corresponds with the view of the neo-institutionalists. When the neo-institutionalist Benavot (1983) argued that national educational systems were becoming increasingly standardized, he argued this by focusing on the decline in the rate of secondary vocational education. Müller and Shavit maintained this focus on rates even while drawing very different substantive conclusions.

Second, the issue of change was explicit in the literature criticized by Müller and Shavit; both neo-institutional theory and the theory of industrialization predicted a convergence in educational systems that Müller and Shavit did not see in the country analyses contained in their volume. To be sure, the authors of the country-specific analyses in the CASMIN project saw change taking place to a greater or lesser extent in the countries they studied: Australia underwent a reform in their secondary schools in the 1960s (Jones 1998). Britain shifted from an emphasis on school type to an emphasis on credentials (Heath and Cheung 1998). France is described as a country that went through dramatic expansion of secondary schools in the 1950s and 1960s (Goux and Maurin 1998), while Germany is described as a country

with very stable educational institutions (Müller, Steinmann, and Ell 1998). The changes described in their volume primarily concern the proportions of students in each country who pursued alternative educational tracks. Changes in the nature of the tracks are sometimes highlighted, though the implications of these changes are left for conjecture, and they do not translate into the major macro-structural dimensions that are used to differentiate among countries.

Third, the consensus in the literature is that school-to-work linkages are indeed stronger in skill formation systems that rely on occupation-specific vocational education and fit the qualificational space ideal type (e.g., Wolbers 2007; Breen 2005; Müller and Gangl 2003). The concept of vocational education is centered on the distinction between specific and general skills. These terms do not have a precise meaning, not so much because the terms are vague as because the world of work is complicated. Specific skills are skills that are specific to particular tasks that occur only in some activities and only in some jobs. General skills are skills that improve functioning on tasks that occur in a wide variety of situations. It is very difficult to measure the specific or general skill content of educational programs. In this respect, it is telling that the UNESCO manual for ISCED 2011 says virtually nothing about how vocational content of vocational (or, for that matter, general) education is measured. Instead, the manual consistently refers to vocational programs as leading directly to the labor market and—at higher levels—sometimes refers to vocational programs as programs that "lead to attestations or certificates for specific occupations" (OECD 2015, p. 65). Hence, it is not surprising that Shavit and Müller emphasized the difference in *rates* of vocational education as the key structural difference between the two ideal-typical regimes (France and Germany) that guided the CASMIN project; the presumption that vocational programs indeed channel graduates to specific occupations is treated as self-evident in the literature.

3 A structural approach to school-to-work linkages

The identification of "structure" with "rates" rests on assumptions that have not been given the attention they deserve. First, it implies that it is possible to identify vocational educational programs and distinguish them from academic programs. Second, it implies that this binary distinction effectively captures the differing implications of these programs for labor market outcomes. From this perspective, the distinction between academic and vocational programs is much more important than are the distinctions among academic or among vocational programs, or the distinctions between vocational programs in one country and in another country, or the distinctions between academic programs in one country and in another country. Under these assumptions, the vocational character of an educational system is largely determined by the rate of vocational education. The focus on rates of vocational education also represents a substantive focus on the country as the unit of analysis (rates are computed for the country as a whole). All of these assumptions are limiting; they conceal important structural differences in educational systems that are rarely studied in the stratification literature

We propose to study the coherence of school-to-work pathways as well as cross-national differences in their composition. Our perspective allows a crucial test of whether – and if yes, by how much – vocational programs are consistently more successful at providing school-

to-work linkages compared to other programs. We call this "linkage approach" a structural approach because it does not rely on classifying programs as vocational or general, and instead measures the "success" of educational programs by studying how closely a program links to specific occupations. The actual content of educational programs is difficult to ascertain, but a central characteristic of vocational programs concerns the extent to which specific educational programs lead to specific occupations. Consequently, the primary observable characteristic of educational programs is the match they produce between specific programs and specific occupations. This characteristic is *jointly* determined by educational content and by legal, cultural, and social characteristics of labor markets. For instance, VET systems typically involve strong regulation of access to occupations as well as specific occupational content in the vocational educational system. Occupational closure, such as the regulation of access via licensing requirements, collective bargaining agreements, and other mechanisms, shape the strength of linkages (Bol 2014; Di Stasio and Werfhorst 2016). As a consequence, it is not theoretically satisfactory to distinguish among countries solely in terms of rates, and it is problematic to consider differences in rates to be the basis for structural distinctions in educational systems.

The structural approach that we favor runs parallel to the dominant frame for social mobility. The mobility structure of a country is commonly conceptualized as an outcome of both the marginal distributions for origin and destination classes and the extent of association between origin and destination classes. Countries can differ from each other (or over time) in their origin marginal distribution, in their destination marginal distribution, and in their level of relative mobility. We argue that a parallel framework to that used for the study of occupational or class mobility similarly illuminates the structure of a country's skill formation system. This framework calls attention to three distinct features.

First, educational systems can differ from each other both in the distribution of students across the various educational tracks and in the credentials available in the system. This feature is similarly a central component of the CASMIN approach as well as of the linkage perspective.

Second, educational systems can differ in the strength of the association ("linkage") between specific educational outcomes and the occupational structure. The linkage perspective provides a clear contrast with the CASMIN approach that focused attention on distributional differences, macro-structural characteristics, and the implications of these macro-structural variables for individual-level mobility outcomes. The linkage perspective instead emphasizes the relational character of educational outcomes and occupational destinations. Rather than classify educational programs as "vocational" or "academic" based on their internal characteristics and intended occupational targets, our approach treats the strength of linkage itself as an object of study. There are, of course, good theoretical reasons to expect some programs to link more strongly to the occupational structure than others, but we argue that a continuous, data-based *measure* of the strength of linkage is more illuminating and empirically plausible than a binary, theoretically motivated *classification* (vocational/academic). Indeed, we expect that some well-developed vocational programs will link strongly to the occupational structure, but others may link relatively weakly. Moreover, some programs that might be seen as "academic" from a conventional perspective may link strongly to the occupational structure, and more strongly than other programs that would conventionally be seen as "vocational."

The **third** feature of the linkage approach is the attention it directs towards linkage patterns as well as linkage strength. Differences across countries or over time in the structure of linkage can arise against a backdrop of common patterns of relative linkage strength, or from qualitative differences in the linkage patterns themselves. In analogy to the class mobility literature (Erikson and Goldthorpe 1992), there may be a "core" model of linkage that applies to many countries, and stronger linkage in one country than another may occur through an overall parameter that well approximates the ratio of linkage strength for most combinations of educational level and field of study. Alternatively, a "unidiff" model might provide a very poor representation of structural differences across countries when comparing educational systems. This is an empirical question whose answer is not yet known.

The linkage perspective provides a framework for addressing the (possibly changing) differences between the educational systems of France and Germany, two countries that Müller and Shavit considered to be the ideal-typical regimes of school-to-work transitions. Already the work of DiPrete et al. (2017) has raised serious questions about the portrait of French-German educational differences that was provided by Maurice, Sellier, and Silvestre (1986) and reinforced by Shavit and Müller (1998). France at present has fewer workers who were educated in programs that have tight linkage to the occupational distribution. At the same time, many of France's educational programs have linkage that is as strong or stronger than in Germany. The differences between Germany and France, in other words, appear to involve both structural and compositional differences. But clearly the portrayal of the French educational system as academic in character with educational level rather than field of study being the dominant characteristic is an oversimplification of a more complex reality.

If France and Germany today are less different than Maurice et al. describe, then either the results from Maurice et al. do not generalize to the full educational and occupational distribution, or the link between school and work in Germany and France has substantially changed over time. We address this puzzle by investigating how the skill formation systems in France and Germany have changed between 1970 and 2010. While Maurice et al.'s study became accepted in the wider stratification literature as the definitive statement on skill formation regimes in France and Germany, we argue that the extrapolation across time, genders, and industries is problematic and requires further investigation.

4 Analytical strategy

To study the co-evolution of educational systems and labor markets since the 1970s, we harmonize several datasets across time for both Germany and France. Our interest lies in the strength of the association between the educational system and the labor market, reflected here by the *educational level* and the *field of study* on the one hand, and *occupations* on the other hand.[2] The main analytical unit is the combination of educational level and field of study ("level-field"). Intuitively, linkage is high when graduates with a specific level-field combination work in a small set of occupations; linkage is low when workers who graduated

[2]Note that we use "field of study" here in a broad sense, referring to all education that is specific to an area of work, including vocational schooling, university degrees, but also the German "Ausbildung" in the dual system.

with that level-field combination end up working more evenly across a number of different occupations.

4.1 Data

The European labor Force Survey (EU-LFS, Eurostat n.d.) is well suited for our purposes because it provides harmonized variables for educational levels, fields of study, and occupations. In the 2005 to 2010 datasets, educational levels and fields of study are coded in the ISCED 1997 scheme, and occupations are coded using ISCO-88 (3 digits). In 2011, the EU-LFS switched to ISCO-08, which is why we use only the years up until 2010. Because of the small sample size in Germany in 2006 to 2010, we pool the samples for 2006-2007, as well as for 2008-2009. In the EU-LFS, no fields of study were recorded before 2005. For France, we additionally used the "Formation et Qualification Professionelle" (FQP, INSEE/ADISP-CMH n.d.(b)) survey for 1970 and 1985, as well as the 1990-2002 series of the French Labor Force Survey (Enquête Emploi, INSEE/ADISP-CMH n.d.(a)). Here, fields of study are recorded consistently beginning in 1995. Again, to increase the sample size, we pooled the years 1995-1997, 1998-2000, and 2001-2002. For (West-)Germany, we use the Public Use Files of the censuses of 1970 and 1987 (RDC of the Federal Statistical Office and Statistical Offices of the Länder n.d.).[3] These surveys differ in their purpose and sample selection. To increase the comparability over time, we restricted all samples to the current active workforce aged 15 to 64, leaving out students and the unemployed.

Educational levels, fields of study, and occupations were recorded in different schemes in many of these years. For educational levels, we used the official ISCED mappings to code degrees into the ISCED-1997 scheme (see Table 1). The EU-LFS does not provide a breakdown for category *3ab*, which combines workers with general and specialized education. We therefore split this category using the field of study information: We code a worker as *3ab_voc* if a worker completed a professional or technological *baccalauréat* (maturity exam) in France or an *Ausbildung* (dual training) in Germany; we code as *3ab_gen* for the general *baccalauréat* in France and the *Abitur* (maturity exam) in Germany. We merge *5a* and *6* (PhD) because the latter is a small category and cannot be distinguished in earlier surveys. We also merge ISCED 0 and 1, because these two categories can not be distinguished in earlier years. In categories *1*, *2* and *3ab_gen*, workers have obtained general education, while in all other categories workers have obtained specialized education (indicated by the presence of a field of study), be it either through dual training, vocational schooling, or in higher education. Programs classified as *5b* are advanced vocational programs on the verge of tertiary education, as they are often completely school-based and last for several years, while programs in *3c* and *3ab_voc* are more often a mix of on-the-job training and school-based training.

Fields of study have been manually coded into ISCED fields of study (one of: Teacher training, education; Humanities, languages, arts; Social sciences, business, law; Science, mathematics, computing; Engineering, manufacturing; Agriculture, veterinary; Health, welfare; Service). The detailed crosswalks are found in the online appendix. Except for the

[3]The Mikrozensus cannot be used for our purposes, because up until 2004 it is missing the field of study for people who were trained in the dual system.

Category	France	Germany
ISCED 1 or less	Elementary education or less	Elementary education or less
ISCED 2	Brevet, BEPC or some secondary education	Hauptschul-/Realschulabschluss
ISCED 3c	CAP, BEP, BP	
ISCED 3ab_voc	Baccalauréat professionnel Baccalauréat technologique	Lehrabschluss, short vocational school
ISCED 3ab_gen	Baccalauréat général	Abitur, Fachhochschulreife
ISCED 4		Abitur/Fachhochschulreife *and* Lehrabschluss
ISCED 5b	DUT, BTS infirmier, assistante sociale	Meister, Techniker, long vocational school (Fachschule, e.g. in health)
ISCED 5a/6	DEUG, License, Maîtrise, Diplôme, etc. DEA, Diplôme de docteur	BA, MA, Diplom, Magister, etc. Promotion

Table 1: ISCED-1997 and native degrees

Note: Adapted from official ISCED mappings for France and Germany (`http://uis.unesco.org/en/isced-mappings`)

FQP survey in 1970, we were able to use proportional crosswalks to harmonize native occupational codings into ISCO-88. To create a proportional crosswalk, we identified surveys where the native occupational scheme and ISCO-88 were coded for the same individuals. For each native code, we then calculated the proportion of double-coded ISCO-88 codes. For instance, the French PCS-1982 code 3751 ("Cadres de l'hôtellerie et de la restauration") is coded in ISCO-88 as 122 (Production and operations department managers) in 58% of the cases, and 131 (General managers) in 42% of the cases. When we apply the crosswalk to our data, we randomly choose with a probability of .58 the ISCO code 122, and 131 otherwise. This process introduces uncertainties into our estimates, which however are in practice very small. We provide an analysis of this uncertainty in the online appendix.

4.2 A measure of school-to-work linkage

To formally measure the strength of the link between educational programs and occupational destinations, we employ a multigroup segregation measure. Specifically, we use the Mutual Information Index, M (Mora and Ruiz-Castillo 2011; Theil 1972; Theil and Finizza 1971), to measure the strength of linkage between level-fields and the occupational distribution. To simplify, we define G as the set of combinations of E educational levels and F fields of study. To calculate M, consider a $G \times J$ contingency matrix of G level-fields and J occupations. From this matrix, we define the marginal probabilities $P_{.g}$ and $P_{j.}$, as well as the conditional probability of being in occupation j given level-field g, $p_{j|g}$.

We define $M(G;J)$ as "total linkage," which measures the dependency between the level-fields and occupations contained within G and J. Linkage is high for a specific level-field when the occupational distribution of that level-field deviates strongly from the overall oc-

cupational distribution. We call this the local linkage L of level-field combination g, and define it as

$$L_g = \sum_j p_{j|g} \ln \frac{p_{j|g}}{p_{j\cdot}}. \tag{1}$$

To characterize the overall linkage, M is defined as the weighted average of local linkage scores:

$$M(G;J) = \sum_g p_{\cdot g} L_g. \tag{2}$$

This additive decomposition of M is helpful in determining where the linkage strength of a country originates.

4.3 Studying change

The M is not a margin-free measure of segregation, i.e., segregation may increase or decrease depending on changes in the marginal distribution of level-fields or occupations. For instance, if linkage is higher for university graduates, and their proportion increases without influencing the local linkage scores, the M will increase as well. For a cross-sectional characterization of linkage, this property of margin dependence is desirable, as Mora and Ruiz-Castillo (2011) show. However, it means that changes in M over time can arise through different mechanisms: either because of a pure change in the margins, without any structural changes, or through a change in the structural association between level-fields and occupations. Given that we are interested in studying differences over time and across countries, we need to adjust for the different marginal distributions.

The structural association between the two variables only changes when the odds ratios of the contingency table change, which does not occur as a mechanical consequence of changes in the marginal distributions. Mora and Ruiz-Castillo (2009) proposed an algebraic formula to decompose the change between two M indices into three terms, one of which is "occupational composition invariant" and is thus supposed to capture structural changes over time. However, because the M is symmetric, the same procedure can also be used to obtain a term that is "level-field composition invariant." This poses a problem of interpretation: Which of these two terms provides a good description of structural changes? We follow Watts (2015) in his conclusion that neither of the two terms adequately captures structural change.

Instead, we adopt a procedure first proposed by Karmel and Maclachlan (1988) in the context of segregation studies, and extended by Elbers (2018). Consider two $G \times J$ contingency matrices for the same country at different points in time, t_1 and t_2. To make a margin-free comparison, we adjust the margins of the contingency matrix at t_1 to be identical to those at t_2. This is achieved by the use of iterative proportional fitting (IPF), where first the row margins of t_1 are scaled towards those of t_2, and then the column marginals of t_1 are scaled towards those of t_2. Repeating this process several times will transform the marginals of t_1 to approach the marginals of t_2, while preserving the odds ratios of the matrix as of time t_1. The process is repeated until the marginals are within 0.001% of the marginals at t_2. We call the resulting, counterfactual matrix t_1'. We then repeat the IPF procedure,

starting from matrix t_2, to arrive at matrix t_2'. These two scenarios differ in the choice of the original matrix: One adjusts from t_1 forward towards t_2, while the other adjusts in a backward direction from t_2 to t_1.

Given the four matrices, we calculate $M(t_1)$ and $M(t_2)$ as the observed linkage at time t_1 and t_2. These are the values that would be computed from tables that have the margins and association structure actually observed at times t_1 and t_2 , respectively. In other words,

$$M(t) = M(a(t); m(t))$$

where $a(t)$ is the association structure at time t and $m(t)$ is the marginal distribution at time t. Using this notation, we can then write $M(t_1') = M(a(t_1); m(t_2))$ as the adjusted t_1 linkage, which can be regarded as the counterfactual linkage at time t_2 if only the margins had changed to equal their values at time t_2 (and $M(t_2')$ is then defined correspondingly, i.e., $M(t_2') = M(a(t_2); m(t_1))$.[4] Because $M(t_2)$ and $M(t_1')$ have the same marginal distributions, they differ only in their association structure (i.e., the odds ratios). The same goes for $M(t_1)$ and $M(t_2')$. We follow Deutsch, Flückiger, and Silber (2009) and use the Shapley decomposition, which results in a simple averaging of the forward and the backward scenarios:

$$\begin{aligned} M(t_2) - M(t_1) = & \overbrace{\frac{1}{2}(M(t_2) - M(t_2')) + \frac{1}{2}(M(t_1') - M(t_1)}^{\Delta_{\text{marginal}}} \\ & + \underbrace{\frac{1}{2}(M(t_2) - M(t_1')) + \frac{1}{2}(M(t_2') - M(t_1))}_{\Delta_{\text{structural}}} \end{aligned} \tag{3}$$

A benefit of this approach is that it allows a further decomposition of the "structural" and the "marginal" component. The marginal change can be further subdivided into two components: one component quantifies the contribution of changing educational marginals and one quantifies the contribution of changing occupational marginals. The structural component can be decomposed into the contributions of each individual level-field. We make use of this property below by summing the contributions of the level-fields using ISCED categories. We report the methodological details on these decompositions in Appendix A.

The method described here can be used to compare any two M measures, where "t_1" and "t_2" can stand either for different points in time, or for different countries at the same time, or even different countries at different times.

5 Results

5.1 Descriptives

Table 2provides descriptive statistics by year for the active labor force aged 15 to 64 in France and Germany. Percentages are reported for gender and age groups, as well as for our three main variables of interest.

[4] In other words, the subscript identifies the association structure and the prime indicates that the marginal distribution from the other end point is being used in the counterfactual calculation.

	Germany				France						
	Census		EU-LFS		FQP		Enq. Emploi			EU-LFS	
	1970	1987	2005	2010	1970	1985	1996	1999	2001	2005	2010
Sample size (in 1000)	1146	1261	185	20	26	28	67	67	45	56	80
Gender											
Female	36	38	45	46	37	42	44	45	45	47	48
Age											
15-24	17	15	6	6	16	13	5	5	6	8	7
25-34	26	26	20	20	22	30	28	28	26	26	25
35-44	23	24	33	28	26	27	31	30	30	29	28
45-54	18	25	27	30	21	20	27	29	29	27	27
55-64	15	10	13	16	15	10	9	8	10	10	12
Educational levels (ISCED)											
ISCED 1	0	1	2	2	42	20	13	10	9	9	6
ISCED 2	32	22	11	8	33	32	22	21	20	18	16
ISCED 3ab_voc	52	52	49	50	16	28	31	31	30	29	27
ISCED 3ab_gen	1	2	4	2	1	3	6	7	7	14	16
ISCED 4	1	2	7	8	3	6	6	6	7	1	1
ISCED 5b	7	8	11	10	2	6	11	12	14	12	14
ISCED 5a/6	7	13	17	19	3	6	11	12	13	17	19
Share of general education only											
General/No field	33	25	17	13	78	58	41	38	36	28	24
Educational fields (ISCED)											
Teacher training, education	2	4	4	4	0	0	0	0	0	1	1
Humanities, languages, arts	2	2	4	4	6	5	4	4	5	8	8
Social sciences, business, law	29	30	30	30	23	28	32	33	33	33	34
Science, maths, computing	2	3	3	3	10	8	3	4	4	8	8
Engineering, manufacturing	50	46	36	34	44	38	38	37	35	31	29
Agriculture, veterinary	4	3	3	3	5	5	5	4	5	4	4
Health, welfare	6	8	13	14	6	11	11	11	11	9	10
Services	5	5	8	8	6	5	7	7	7	5	6
Occupation (ISCO-88, 1 digit)											
Armed forces	1	1	1	0	1	1	1	1	1	1	1
Managers/Senior Officials	3	5	6	6	8	7	8	8	8	8	9
Professionals	7	11	15	16	6	8	10	10	11	13	14
Technicians/Assoc. Profess.	17	21	22	22	10	15	17	17	18	18	19
Clerks	11	13	12	12	11	15	15	15	14	12	11
Service/shop workers	9	10	12	12	6	9	12	12	12	13	13
Skilled agricultural workers	5	3	2	2	15	8	5	4	4	4	3
Craft and related workers	25	20	15	14	20	16	14	14	13	12	11
Plant operators/assemblers	10	8	8	7	10	13	11	11	11	9	9
Elementary occupations	11	10	8	8	13	8	8	8	8	10	10

Table 2: Descriptive statistics by year

Notes: All numbers except sample size are percentages. For reasons of space, only years 2005 and 2010 are shown for the EU-LFS.

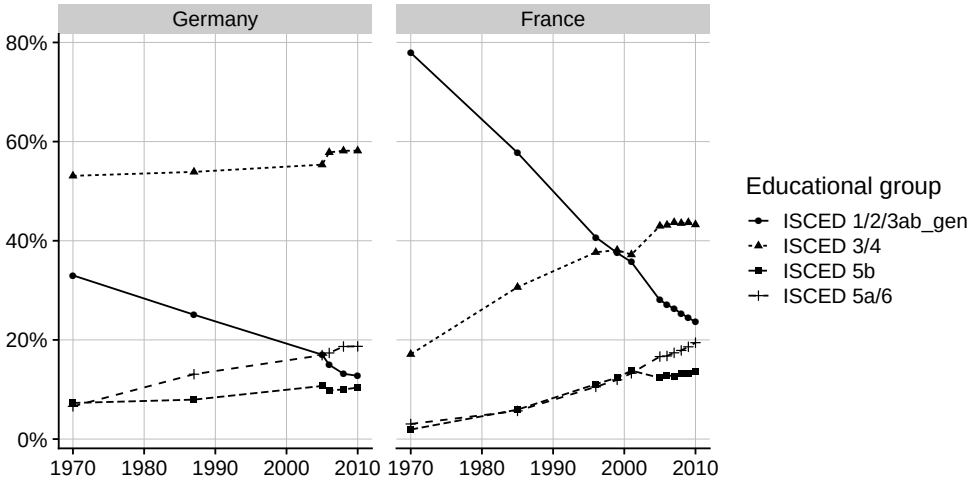

Figure 1: Share of ISCED levels over time

The tables confirm the well-known patterns of the changing demographics of labor force participation. Women's labor force participation increased from 38% to 48% in France and from 36% to 46% in Germany – always slightly below the French levels. The changes in the age structure reflect both an aging population and an increase in educational attainment. Many of those aged 15-24 in 1970 were already in the labor force, while in 2010 many in this age group are still in vocational or tertiary education, entering the labor market at older ages.

Of special interest are the dramatic changes in the educational structure. To simplify the presentation, we group ISCED levels *1*, *2*, and *3ab_gen*, which are general levels for which there are, by definition, no fields of studies defined. We also group ISCED levels 3 and 4, which represent vocational education. Figure 1 shows that in both countries, the effects of educational expansion are clearly visible, with increases in vocational and tertiary education and strong declines in the share of unspecialized workers. However, the figure also shows clear differences in the two countries' skill-formation systems. In 1970 Germany, roughly 60% of the labor force had undergone vocational education, compared to about 20% in France. Since then, the educational composition of France's labor force has changed dramatically. France's educational distribution in 2010 resembles Germany's distribution in 1970. Both vocational and tertiary education in France have increased enormously, leading to a labor force in 2010 with over three quarters of the workers having some sort of specialized education, up from less than one quarter in 1970. This underscores the stability of the German skill formation system compared to a number of educational reforms in France that aimed to increase vocational and tertiary education levels (Day 2001; Brauns et al. 1999). This pattern of stability in Germany and change in France is a recurring theme in this paper.

Vocational education is traditionally focused on manufacturing and business degrees, which in both countries constitute the majority of degrees awarded. With industrialization and an increasing focus on service occupations, the *relative* share of manufacturing degrees has decreased markedly over time in both countries. The increasing diversity of vocational

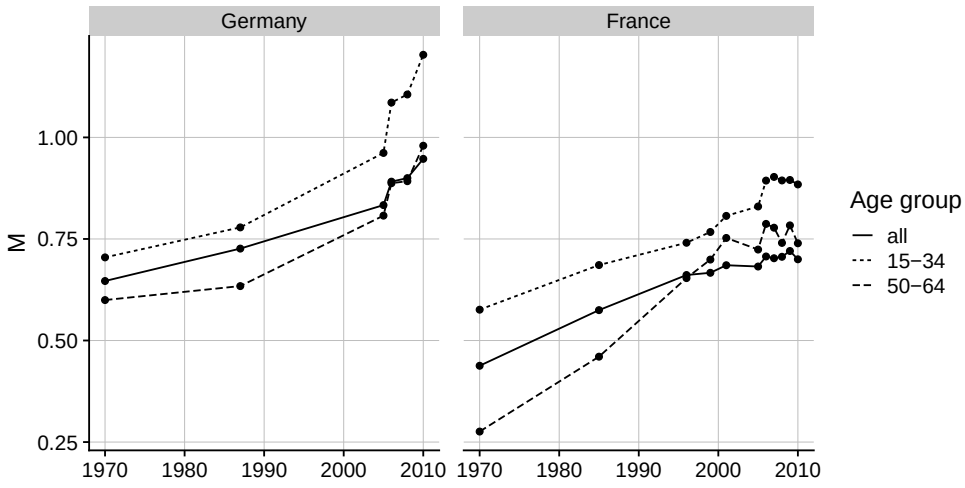

Figure 2: Aggregate linkage over time, for total labor force and younger (15-34) and older (50-64) workers

education is reflected by an increase in health, welfare, and services degrees. When comparing the distribution of fields of study between the countries, they show a roughly similar pattern.

Both the distribution of occupational major groups and the patterns of change are similar in both countries, suggesting changes in the skill distribution of the labor force that are common to both economies. The growth in both countries has been concentrated in high- and medium skilled occupations (groups 1 to 5), while lower-skilled occupations have declined (groups 6-9). There are also some important differences between France and Germany that seem stable over time. In both 1970 and 2010, Germany had more workers in craft and professional occupations (groups 2, 3, 7), while France had more workers in agriculture, low-skilled, and management occupations (groups 1, 6, 9). This pattern is consistent with Maurice et al.'s findings about the organization of work in the two countries. In France, the number of low-skilled workers and managers is higher, while Germany relies more on specialized, "medium-skilled" workers.

5.2 Observed total linkage over time

Figure 2 shows the strength of linkage for France and Germany for the whole labor force, and for young and old workers separately. The M is measured for each year and country separately and defined by applying eq. 2 to the matrix of level-fields and three-digit ISCO-88 occupations. In 2010, Germany's M was about 38% higher than France's, which is similar to the difference reported in DiPrete et al. (2017), who used different datasets. In 1970, Germany's M was 50% higher than France's. Since 1970, Germany's M has increased by 56%, and France's M by 70%, with most of this change occurring before 2000. In terms of total linkage, the countries have thus slightly converged over time.

The figure also includes estimates for young and old workers. As expected, younger workers who have just begun their careers link more strongly than older workers. Especially in Germany, linkage levels in the cross-section do not differ much by age, which suggests

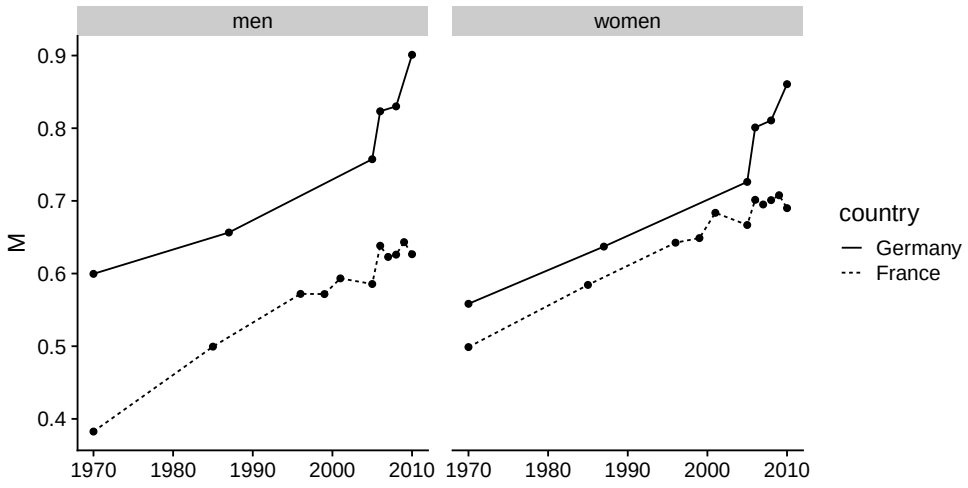

Figure 3: Gender-specific patterns of linkage

a relative stability of educational institutions across cohorts. In France, major differences between age groups are observed in the years 1970 and 1985, but not in later years. All the following results are calculated on the whole labor force.

A rarely-discussed aspect of Maurice et al.'s comparative study is that it focused only on large industrial firms and only on the male labor force. The point about gender was argued by Marry et al. (1998):

> The majority of these studies have only been concerned with men [...], and one could ask whether the label "societal" is really appropriate for characteristics measured only for the masculine half of society. (p. 356)

To analyze gender-specific patterns, we calculated the M index separately for men and women (Figure 3). When taking into account only men, France and Germany indeed look very different, supporting Maurice et al.'s findings. However, the picture is starkly different for women. Especially during the 1970s (the likely period of Maurice et al.'s research), linkage for women is only slightly higher in Germany than it is in France. These findings call into question the neat separation of the German and French skill formation systems, and call attention to the fact that the original classifications developed by Maurice et al. are only applicable to part of the labor force.

Next, we use eq. 2 to study where the linkage strength in Germany and France originates. The full decomposition of local linkage scores gives 35 terms, one for each level-field.[5] For a more parsimonious presentation, we sum the contribution of level-fields to the total M by simplified ISCED levels (same as in Figure 1). The four components are plotted separately by country-years in Figure 4. The percentage indicates the relative contribution towards total linkage strength, and this number can be compared to the proportion of this level among the labor force from Tables **??** and 2.

[5]There are four ISCED levels within each country with field information, and three general levels without field information. Given that there are 8 fields of study, there are 35 level-fields in total i.e. $3 + 4 \times 8 = 35$. Because not all level-field combinations are present in each country-year, the actual number of level-fields is lower.

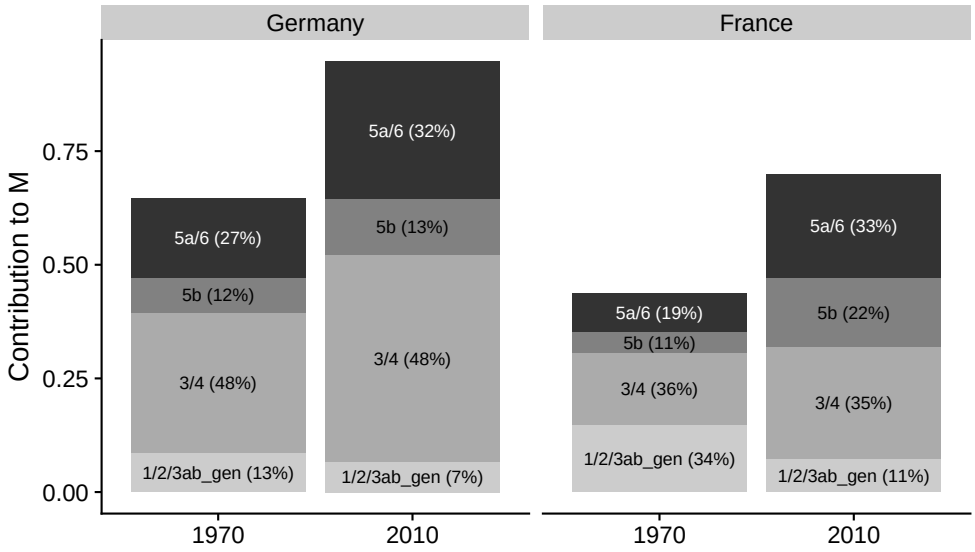

Figure 4: Decomposition of M by ISCED levels

In Germany, almost half of the linkage strength in 1970 originates from ISCED levels 3 and 4. Although only 7% of graduates had obtained tertiary education (*5a/6*), this component accounts for 27% of linkage strength. General education (i.e., ISCED *1*, *2*, and *3ab_gen*) comprised one third of Germany's labor force in 1970, but contributes only 13% to total linkage strength. In 2010, these relative contributions have changed only little, and seem to be mostly explained by changes in the relative proportions. Tertiary education has grown, while general education has declined. ISCED levels 3, 4, and 5 have grown as well (at the expense of general education), but these do not contribute much more towards the explanation of total linkage.

As we have seen above, France in 1970 was dominated by general education. 78% of the labor force had a general degree, and this group contributes 34% towards linkage strength. While the other three components (ISCED 3/4: 17%, 5b: 2%, 5a/6: 3%) together constitute only a small labor share, they contribute a considerable amount of the total linkage strength. Two thirds of France's linkage in 1970 originates from just 22% of the labor force—implying that this small share of the labor force linked quite well to the labor market. In 2010, France's educational distribution has gone through enormous changes. This is also reflected in a different pattern of linkage: General education now contributes much less to linkage, and the contributions of ISCED 5 and 6 have grown.

5.3 Between-country differences: then and now

As we noted above, stratification research has often equated high *rates* of vocational training with high vocational specificity and treated this as a structural feature of the country's educational system. Figure 4 already shows that this conclusion might not be justified: In France in 1970, vocational graduates (in ISCED groups 3/4) were only a small share of the labor force, but this group linked strongly to the labor market. Thus, the internal structure of school-to-work linkages in France and Germany does not match the conven-

	All workers				Male				Female			
	1970	(%)	2010	(%)	1970	(%)	2010	(%)	1970	(%)	2010	(%)
M Germany	0.64		0.92		0.59		0.87		0.56		0.82	
M France	0.43		0.68		0.37		0.60		0.49		0.66	
Difference	−0.22	(100)	−0.24	(100)	−0.22	(100)	−0.27	(100)	−0.07	(100)	−0.16	(100)
Total marginal	−0.22	(103)	−0.08	(34)	−0.27	(122)	−0.05	(19)	−0.11	(158)	−0.06	(41)
Educational	−0.22	(100)	−0.03	(12)	−0.26	(115)	−0.02	(7)	−0.10	(143)	0.00	(−1)
Occupational	−0.01	(2)	−0.05	(20)	−0.01	(6)	−0.04	(13)	−0.00	(4)	−0.07	(44)
Total structural	0.01	(−3)	−0.16	(66)	0.05	(−22)	−0.22	(81)	0.04	(−58)	−0.09	(59)
ISCED 1	−0.03	(12)	−0.01	(5)	−0.04	(16)	−0.02	(6)	−0.02	(29)	−0.01	(6)
ISCED 2	−0.06	(29)	−0.02	(10)	−0.06	(27)	−0.03	(12)	−0.06	(88)	−0.02	(14)
ISCED 3ab_gen	0.02	(−9)	0.00	(−1)	0.01	(−6)	0.00	(−1)	0.03	(−41)	0.00	(−2)
ISCED 3/4	0.04	(−17)	−0.09	(37)	0.05	(−22)	−0.10	(38)	0.06	(−92)	−0.08	(49)
ISCED 5b	0.04	(−21)	−0.01	(3)	0.07	(−31)	−0.02	(8)	0.03	(−40)	0.01	(−6)
ISCED 5a/6	−0.01	(2)	−0.03	(12)	0.01	(−6)	−0.05	(18)	−0.00	(6)	0.00	(−1)

Table 3: Decomposition of M between countries (differences are France minus Germany).
Note: To produce this table, ISCED categories *3c*, *3ab_voc*, and *4* have been collapsed into ISCED 3/4, because some of these categories only exist in one of the two countries. For this reason, the M values do not line up completely with Table 4.

tional wisdom about these two countries. However, the findings presented so far have to be interpreted with caution, as they do not fully account for changes in the educational and occupational marginal distributions. Clearly, comparisons between countries and over time can be misleading when approached through Figure 4. We therefore move on to more thorough decompositions that allow us to disentangle structural and marginal changes between the two countries, and also within the two countries over time.

To disentangle marginal and structural changes, we apply eq. (3) to the differences between countries, both in 1970 and in 2010.[6] (Note that t_1 here stands for Germany, and t_2 for France). The results are shown in Table 3. The difference in M values is decomposed into a "total marginal" and a "total structural" component, which are then further decomposed into two and six subcomponents, respectively. In 1970, France's linkage was lower than Germany's, but this difference is completely accounted for by differences in the educational marginal contributions. In the aggregate, there are no structural differences between France and Germany, although the further decomposition of the structural component reveals that graduates of ISCED *3*, *4*, and *5b* had, in fact, higher structural linkage in France than in Germany. When compared separately by gender, the patterns are similar, and the trends towards higher structural linkage in France is even more profound.

In 2010, the pattern has changed: While the differences in M remain, they are now to a much lesser degree explained by marginal differences. Instead, two thirds of the difference in M between Germany and France are now explained by structural differences. Most striking about these results is that for graduates of ISCED *3*, *4*, and *5b*, the relative country ranking

[6]From this section on, we combined ISCED categories *3c* and *3ab_voc* in France, and *3ab_voc* and *4* in Germany into a category ISCED 3/4 to achieve greater comparability between the two countries.

on the structural component of linkage has reversed. In 2010, the average graduate of these levels had higher linkage in Germany compared to France. In both 1970 and 2010, the occupational marginal distribution contributes relatively little to linkage differences, which is likely a reflection of the fact that the country differences in the educational distribution are much more pronounced than the country differences in the occupational distribution. Given the convergence in educational distributions between Germany and France since 1970 — mostly reflected by the expansion of vocational training in France, with less change in Germany — it is also not surprising that the country differences in the educational marginal distributions contribute much less to the overall country difference in M in 2010 than they do in 1970.

The decomposition of the between-country structural difference into the six ISCED levels in Table 3 is a function of both the relative size of the educational levels in the two countries and the differences in local linkage scores (see Appendix A). In Figure 5, we plot the differences in IPF-adjusted local linkage scores for each level-field by averaging over the forward and backward transformations, i.e. $1/2\,(L_g(t_{\text{Fra}}) - L_g(t'_{\text{Ger}})) + 1/2\,(L_g(t'_{\text{Fra}}) - L_g(t_{\text{Ger}}))$. This figure thus answers the question: what is the difference in local linkage scores between the two countries after adjusting for the difference in the occupational distributions? For 1970, the figure shows that the advantages in vocational structural linkage in France stem largely from ISCED category *5b*, and to a lesser extent, from ISCED *3/4*. In 1970, a graduate in ISCED *5b* in Engineering or Manufacturing could thus be expected to link more closely to the labor market in France than in Germany. For tertiary education, the differences are smaller, with no country having uniformly higher linkage. In 2010, the picture has changed markedly: Most of the level-fields are now concentrated on the left side of the graph, indicating moderately higher linkage in Germany for most level-fields. Differences continue to be small for tertiary education.

5.4 Within-country change over time

The results from the previous section indicate that there was substantial change over time between the two countries, which implies that at least one of the countries must itself have changed over time. Given that the structural differences between Germany and France are much more pronounced in 1970 and 2010, it is possible that Germany has increased its structural linkage, France has lost some of its structural linkage, or a combination of these two processes. To answer this question, we again use eq. (3), but this time we apply this decomposition to study change within each country over time. The results are shown in Table 4.

As seen in Figure 2, observed total linkage has increased in both countries at roughly comparable rates. However, the decomposition reveals that the reasons for this increase are starkly different. In Germany, the counterfactual scenario shows that the *structure* of linkage between educational programs and occupational destinations is almost equally strong in 1970 and 2010. The rise in linkage strength is due to rapid growth in educational credentials that link more strongly to the occupational structure. To be precise, 86% of the total difference can be explained by changes in the educational and occupational distributions, with the remaining 14% explained by *increasing* structural linkage. Structural linkage in Germany has grown more rapidly for men than for women.

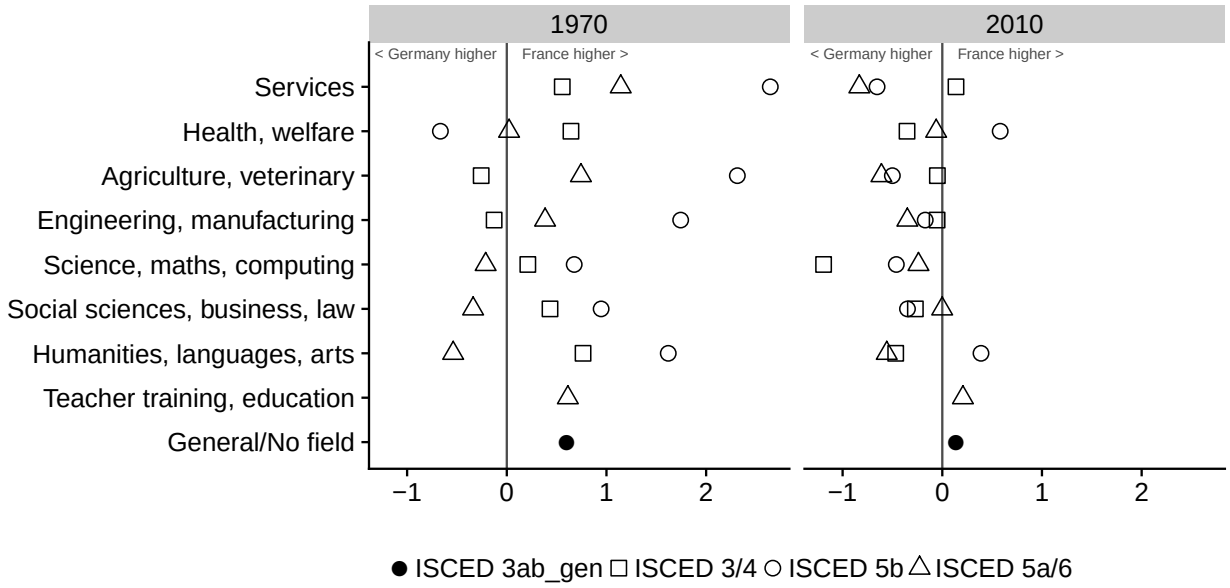

Figure 5: Unweighted structural differences between countries for 1970 and 2010, by level-field

Note: For clarity, ISCED categories 1 and 2 are not shown.

	All workers				Male				Female			
	Germany	(%)	France	(%)	Germany	(%)	France	(%)	Germany	(%)	France	(%)
M 1970	0.64		0.43		0.59		0.37		0.56		0.49	
M 2010	0.92		0.68		0.87		0.60		0.82		0.66	
Difference	0.27	(100)	0.25	(100)	0.27	(100)	0.23	(100)	0.27	(100)	0.18	(100)
Total marginal	0.24	(86)	0.48	(191)	0.16	(59)	0.41	(179)	0.25	(93)	0.52	(296)
Educational	0.17	(63)	0.49	(195)	0.14	(51)	0.48	(210)	0.16	(60)	0.45	(257)
Occupational	0.06	(23)	−0.01	(−3)	0.02	(7)	−0.07	(−30)	0.09	(33)	0.07	(38)
Total structural	0.04	(14)	−0.23	(−91)	0.11	(41)	−0.18	(−79)	0.02	(7)	−0.34	(−196)
ISCED 1	0.00	(1)	−0.01	(−5)	0.00	(1)	−0.00	(−2)	0.00	(1)	−0.02	(−11)
ISCED 2	−0.01	(−3)	−0.01	(−5)	−0.00	(−1)	−0.00	(−2)	−0.00	(−2)	−0.03	(−15)
ISCED 3ab_gen	−0.00	(−2)	−0.01	(−5)	−0.00	(−1)	−0.00	(−2)	−0.00	(−1)	−0.02	(−14)
ISCED 3/4	0.03	(9)	−0.10	(−39)	0.06	(22)	−0.07	(−32)	0.01	(4)	−0.15	(−87)
ISCED 5b	0.02	(9)	−0.04	(−15)	0.04	(16)	−0.05	(−23)	0.01	(3)	−0.03	(−16)
ISCED 5a/6	−0.00	(−0)	−0.06	(−23)	0.01	(4)	−0.04	(−19)	0.00	(2)	−0.08	(−48)

Table 4: Decomposition of M within countries over time

Note: To produce this table, ISCED categories *3c*, *3ab_voc*, and *4* have been collapsed into ISCED 3/4, because some of these categories only exist in one of the two countries. For this reason, the M values do not line up completely with Table 4.

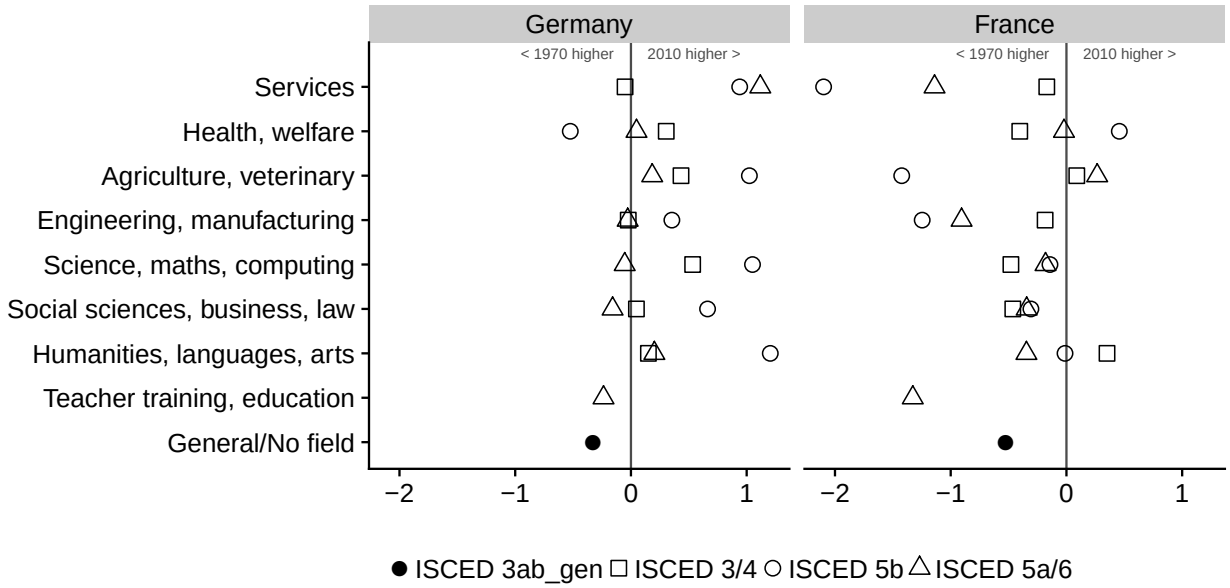

Figure 6: Unweighted structural differences within countries, by level-field
Note: For clarity, ISCED categories 1 and 2 are not shown.

In France, however, marginal and structural change have different signs, and thus partially offset each other. Due to educational expansion, the change in the marginal educational and occupational distributions point to a large *increase* in linkage. In fact, if in France only the educational marginals had changed, France in 2010 would have almost the same total linkage strength as Germany ($.43 + .48 = .91$). However, a large and *negative* component of structural change offsets a large part of the increase that would be expected from changes in the marginals alone. Much of the decrease in structural change is due to declines in ISCED categories *3/4*, and women have been much more affected by declines in structural linkage than men.

As before, we can also study differences in occupations-adjusted local linkage scores, i.e. $1/2\,(L_g(t_2) - L_g(t_1')) + 1/2\,(L_g(t_2') - L_g(t_1))$. Figure 6 shows that ISCED category *5b* again plays a crucial role: in Germany this category overall shows the strongest increases in linkage strength, while in France, this category is where many of the strongest *decreases* in linkage strength are situated. Clearly, most level-fields have increased in local linkage in Germany, and declined in France. With the exception of Services, Engineering and Manufacturing, and Teacher training, changes in local linkage for tertiary education have been small. This is another strong indication that tertiary education is unaffected from the changes in the vocational skill formation system. Both over time and between countries, structural differences in tertiary education are small. In this sense, school-to-work linkages in tertiary education are very similar between these two countries and over time, while the differences for vocational education are more pronounced.

6 Discussion: A historical perspective

Using data that span the 40 years from 1970 to 2010, we find that an in-depth comparison of the French and German skill formation systems leads to a more complex picture than commonly assumed. The French skill-formation system went through dramatic change in the 40 years between 1970 and 2010. In 1970 France, only a small part of the workforce obtained vocational education, but this training was effective in providing linkage towards specific occupations—even more so than in Germany at the time! This runs counter to the claims made by Maurice et al. Since then, vocational education has rapidly expanded in France, but this training no longer provides such effective linkage. The country differences have reversed: While vocational training in 1970 France was considerably more effective in providing linkage than Germany's vocational training, vocational education in Germany today is more effective than in France. Our findings highlight the importance of distinguishing between margins and structure: In 1970, Germany was much more vocationally oriented than France, but did not provide higher linkage. In 2010, the educational distributions of the two countries have converged, but Germany provides higher linkage.

The literature on educational institutions supports these findings, and provides an explanation for the decrease in structural linkage in France. It is generally argued that over the past 50 years, France underwent more severe educational reforms than Germany. The French expansion both at the vocational and the tertiary level was produced by a series of significant reforms—often with explicit reference to the situation in Germany. Charles Day's (2001) history of French vocational and technical education focuses on the institutional fragmentation of general and technical education. Day traces this back to as early as 1890, when the new technical schools were placed under the direction of the ministry of commerce, instead of the ministry of education. This institutional split deepened, and by 1900, the "technical division" had developed a complete educational system on its own, with its own primary, secondary, and tertiary schools. The technical division catered to a selected group of students and aimed to provide high-level vocational training and schooling—a vast difference to Germany's vocational training that, even in the 1970s, can already be characterized as a system "for the masses." The selective nature of vocationally-trained workers in 1970 France aligns with the high amount of structural linkage that we observe for France in 1970, especially for well-trained vocational graduates.

The situation in France is exemplary of the contentious debate about the goals of general versus skilled education, neatly summarized by the opposing poles of the ministries of commerce, favoring specialized education with the backing of industry, and the ministry of education, arguing for a civic ideal of education. The integration of the two systems, while proposed several times in the course of the 20th century, did not occur until 1960. Since then, various reforms followed that expanded vocational education at different educational levels. Of special note is the "loi Jospin" from 1989, named after the education minister, which formulated the goal that "all young people reach a recognized level of training" (n.a. 1996, p. 49).

Meanwhile, France continued to lack the "decentralized cooperation" between unions, employers, and the state that characterized Germany (Hall and Soskice 2001). It could well be that this lack of decentralized cooperation created imbalances in the supply and demand of workers who were graduating from the expanding specialized educational programs in France.

The weaker regulation might also have given French employers greater flexibility in hiring workers whose credentials were not the natural match to the jobs but who otherwise were judged by the employers to be good fits. Either or both of these mechanisms could explain the combination of growing composition-based linkage strength and declining structural-based linkage strength in France.

The contentious history of educational reforms in France contrasts markedly with the German situation (Brauns et al. 1999). The basic system in Germany has been in place since the late 19th century, and despite the two world wars and the political upheavals, has changed only little (Thelen 2004). The German arrangement of vocational ("dual") training has existed since the late 19th century, and relies on close coordination between industry and the educational system. Reforms were planned in Germany as well, especially by the social-democratic governments (1969-1982), and were aimed to remove early tracking or replace some of the vocational training with more general, school-based training. However, these reforms were not implemented. This is clearly visible in our results, which show that in Germany almost no structural change can be observed.

7 Conclusions

We find that the German vocational system in 1970 was not—on average—substantially more efficient in allocating graduates to specific occupations. This finding is a major departure from the results presented by Maurice et al. Rather, the main reason that Germany had higher total linkage is because more students were enrolled in secondary-level vocational programs in Germany than in France. Since the 1970s, Germany has expanded quantitatively in both vocational and tertiary education, without substantial reforms that would have altered school-to-work linkages. In France, on the other hand, we observe a large increase in vocational and tertiary graduates. This increase was accompanied by a decline in structural linkage, which has been especially pronounced for vocational graduates. Our results underscore the importance of attending to structural as well as compositional differences in educational systems across countries and over time. Whereas the vast majority of the literature has treated skill formation systems as being vocational or general based on the size of either sector, we show that in order to understand cross-national differences in school-to-work linkages it is crucial to understand how strongly educational programs link.

So can we still talk about France and Germany as the ideal-types of respectively "organizational" and "qualificational" spaces? Our results show that this is not the case. In the 1970s France and Germany were much more similar in the way students were allocated to occupations in the labor market. While there were more vocational graduates in Germany than in France, the extent to which they were matched to occupations is similar. Moreover, we find that for these classifications it is crucial to distinguish between men and women. For male workers the differences between France and Germany are apparent. For female workers, France and Germany were very similar in the 1970s and have remained similar since then.

Our results raise the more general question whether the crude cross-national classifications of skill formation systems that are dominant in the current literature do justice to actual cross-national differences. We believe this not to be the case. When looking more closely into how school-to-work linkages are established, countries might be similar on some

aspects (structural linkage), but differ on others (composition of workers across the programs). Moreover, the differences *within* countries are as large or larger than differences *between* countries. Lastly, we find that graduates in tertiary education have linked more similarly across time and space than have vocational graduates. The characterization of skill-formation systems as qualificational or organizational might thus be even less appropriate when a large fraction of the labor force has attained tertiary education. Future research should move beyond treating countries as entities with homogeneous skill formation systems that are stable over time. We show that school-to-work linkages vary starkly both within countries and over time.

Appendix A: Full decomposition

In the following, we describe how the marginal and structural components obtained in eq. 3 can be further decomposed.

The changes in the marginal component can be decomposed into two components for the educational and occupational distribution, respectively. To do this, we consider all the ways in which either marginal component can be eliminated. For this, we need to consider all possible combinations between educational marginals, occupational marginals, and odds ratios from both t_1 and t_2. As a shorthand notation, we will write $M(G; J; O)$ to identify the M that is calculated based on the educational marginals from G, the occupational marginals from J, and the odds ratios from O. For instance, $M(t_1) = M(t_1; t_1; t_1)$ and $M(t_1') = M(t_2; t_2; t_1)$. Given all possible combinations, there are eight unique matrices, including the two unaltered ones. This decomposition thus requires six distinct IPF procedures. The decomposition then relies on averaging all possible elimination strategies. To quantify the effect of marginal change in the educational distribution, there are four possible elimination strategies:

$$\begin{aligned}\Delta_{\text{education}} = &\frac{1}{4}(M(t_2; t_1; t_1) - M(t_1; t_1; t_1)) + \frac{1}{4}(M(t_2; t_2; t_1) - M(t_1; t_2; t_1)) \\ &+ \frac{1}{4}(M(t_2; t_2; t_2) - M(t_1; t_2; t_2)) + \frac{1}{4}(M(t_2; t_1; t_2) - M(t_1; t_1; t_2))\end{aligned}$$

Note that within each subtraction, only the educational margins are changed, with the other two factors held constant. Similarly, for the occupational distribution:

$$\begin{aligned}\Delta_{\text{occupation}} = &\frac{1}{4}(M(t_1; t_2; t_1) - M(t_1; t_1; t_1)) + \frac{1}{4}(M(t_2; t_2; t_1) - M(t_2; t_1; t_1)) \\ &+ \frac{1}{4}(M(t_2; t_2; t_2) - M(t_2; t_1; t_2)) + \frac{1}{4}(M(t_1; t_2; t_2) - M(t_1; t_1; t_2))\end{aligned}$$

The sum of $\Delta_{\text{education}}$ and $\Delta_{\text{occupation}}$ equals Δ_{marginal} from (3).

The term for the structural component admits a straightforward decomposition based on local segregation scores. The key property that these decompositions exploit is that $p_{\cdot g}^{t_2} = p_{\cdot g}^{t'_1}$, $p_{j\cdot}^{t_2} = p_{j\cdot}^{t'_1}$, $p_{\cdot g}^{t_1} = p_{\cdot g}^{t'_2}$, and $p_{j\cdot}^{t_1} = p_{j\cdot}^{t'_2}$, i.e. the equivalence of the margins. We can thus write:

$$\begin{aligned}
\Delta_{\text{structural}} &= \frac{1}{2}(M(t_2) - M(t'_1)) + \frac{1}{2}(M(t'_2) - M(t_1)) \\
&= \sum_g \left(\frac{1}{2} p_{\cdot g}^{t_2} \left[L_g(t_2) - L_g(t'_1) \right] + \frac{1}{2} p_{\cdot g}^{t_1} \left[L_g(t'_2) - L_g(t_1) \right] \right) \\
&= \sum_g \left(\frac{1}{2} p_{\cdot g}^{t_2} \left[\sum_j^G p_{j|g}^{t_2} \ln \frac{p_{j|g}^{t_2}}{p_{j\cdot}^{t_2}} - p_{j|g}^{t'_1} \ln \frac{p_{j|g}^{t'_1}}{p_{j\cdot}^{t_2}} \right] + \frac{1}{2} p_{\cdot g}^{t_1} \left[\sum_j^G p_{j|g}^{t'_2} \ln \frac{p_{j|g}^{t'_2}}{p_{j\cdot}^{t_1}} - p_{j|g}^{t_1} \ln \frac{p_{j|g}^{t_1}}{p_{j\cdot}^{t_1}} \right] \right)
\end{aligned}$$

where $L_g(X)$ refers to the local segregation score for educational degree g in matrix X. The difference in structural segregation can thus be attributed solely to differences in the conditional probabilities, holding the marginals constant.

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