School-to-Work Linkages in the United States, Germany and France

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Abstract

A new analytical approach is presented for assessing the strength of linkages between educational credentials, including fields of study, and occupational positions. Building on recent advances in the study of multi-group segregation, the new approach finds substantial differences in school-work linkage strength across the U.S., France, and Germany, but at the same time demonstrates that existing approaches exaggerate the extent of within-country homogeneity of a country's strength of linkage across educational categories and occupations. The new approach clarifies the source of differences in country linkage strength in terms of differences related to educational levels vs. fields of study. The approach also identifies the extent of cross-national differences in the strength of linkage that stem from cross-national differences in the educational and occupational marginal distributions as opposed to differences in the strength of the component linkages that contribute to a country's overall linkage strength. The paper discusses the research questions that are potentially informed by the new approach (educational completion rates, occupational mobility over the work career, wage and earnings inequality, co-evolution of labor market and educational institutions, etc.). It then illustrates the substantive importance of the new approach by showing first that the standard "organization space-qualification space" distinction poorly describes the contemporary difference between Germany and France, and second by showing that relative mean occupational wages in Germany and the U.S. vary directly with the relative linkage strength for occupations in the two countries.

1 Introduction

Industrialized countries differ in the character of their educational systems. Many studies suggest that qualitative characteristics of educational systems are important for skill formation, for credentialing, and for the specific pattern of linkages between education and the labor market. These institutional characteristics affect the distribution of skills and the "returns" to education of school leavers, measured alternatively in terms of unemployment rates and wage and occupational outcomes of young workers (Shavit and Müller, 1998; Müller and Gangl, 2003a; Wolbers, 2007; Andersen and Van De Werfhorst, 2010). They also affect the wage and occupational status returns to fields of study in most or all countries (Van de Werfhorst, 2004; Reimer et al., 2008; Altonji et al., 2012). As Hall and Soskice (2001) have argued, these institutional configurations that link education, training and the labor market constitute different "varieties of capitalism," which have developed over the specific histories of countries from efforts by firms to solve coordination problems in the market, from political conflict involving labor and capital, unions, firms, and political parties, and from state actions in response to both market and political challenges (Streeck, 2005; Thelen, 2004; Busemeyer and Trampusch, 2012; Anderson and Hassel, 2013). These arrangements are seen as having broad consequences not only for skill distributions of workers but also for the national economy, the distribution of wages and earnings, and the level of inequality.

The comparative stratification literature in sociology has made significant progress in understanding how educational systems differ along major institutional dimensions and how these dimensions affect employment and occupational outcomes for both younger and more established workers. The comparative political science literature has helped to identify the historical factors that create path dependence as common global forces challenge the institutions of different countries. But even though both literatures acknowledge that "training regimes" (Busemeyer and Trampusch, 2012) are heterogeneous across nations, research too often has treated these regimes as undifferentiated characteristics of countries that potentially influence stratification outcomes such as the unemployment rates of young workers or occupational status returns to education. The possibility that institutional effects are heterogeneous – meaning that they produce more tightly coupled outcomes in some parts of the "training space" than others, and therefore lead to varying country differences depending on educational levels or fields of study –remains largely un-

examined. In addition, the sociology literature hardly has addressed the potential consequences of different education and training systems for the structure of inequality in different countries. The political science literature has asserted a potential connection between training regimes and wage structures, but has empirically examined the connection at too high a level of abstraction – treating countries as units of analysis and searching for effects of a training regime on inequality, controlling for other aggregate country characteristics. The economics literature has done the most extensive investigations of wage and earnings inequality at the national level, but this work does not examine the impact of institutional characteristics of training regimes or the link between education and occupations on the structure of inequality.

In this paper we advance the literature by examining linkages between detailed educational and occupational categories. We define the strength of linkages first in terms of the strength of association between school-leaving credentials and labor market position. For any given school-leaving credential, a strong linkage occurs when school leavers with that credential cluster in a relatively small number of labor market positions. When field of study is taken into account, the clustering should be even stronger. Relying on statistical methods to assess multi-group segregation (Mora and Ruiz-Castillo, 2011; Theil and Finizza, 1971; Theil, 1972; Reardon and Firebaugh, 2002), we study whether people who have obtained a specific level of education and specific field of study within this level are employed in many different kinds of occupations (weak linkage), or a more restricted set of occupations (strong linkage). We use segregation indices to assess how strongly aligned people of different detailed educational categories are across a large number of occupations, with stronger alignment pointing towards stronger linkages between education and occupation.

We compare the school-to-work linkages in the United States with those in two other countries that have been seminal examples of different types of training regimes, namely Germany and France (Maurice, Sellier, and Silvestre, 1986; Shavit and Müller, 1998). The educational systems and labor market regulations are known to differ substantially across Germany, France, and the U.S., plausibly leading to strongly divergent linkages between educational qualifications and occupational positioning. We make this comparison because of its inherent substantive interest and also as an illustration of the potential of the new analytical approach for providing new insights into national institutional structures that arguably affect rates of educational attainment, school

to work transitions, unemployment, career mobility, educational expansion, and wage and earnings inequality.

We use country specific labor force surveys with a large number of observations to estimate the strength of linkages in the three countries at a level of resolution (about 80 educational categories and 90 occupations) that is considerably greater than has previously been studied in the comparative literature with nationally representative data. We use decomposition techniques to identify the source of linkage strength in the educational levels and fields of study of a country's educational system. We then test the argument that these educational categories play a different role in sorting workers into occupations in countries whose training regime is thought to be based on what Maurice et al. (1986) referred to as "organizational" as opposed to "professional/qualification" principles. We also show how knowledge of the linkage structure of a country is informative about the structure of its earnings inequality within and between occupations.

Our results provide a country ordering that matches theoretical expectations but at the same time reveals previously unknown and therefore unappreciated aspects of institutional structure that have important effects on stratification outcomes. First, linkage strength is not homogeneous within countries, but varies across educational credentials as well as across occupations. Second, country differences in linkage strength also vary considerably across educational credentials as well as across occupations; in other words aggregate differences in linkage strength across countries mask a considerable variation in the size of country differences at the level of educational categories or occupations. Third, the long argued structural difference between the effects of training on occupational placement in France and Germany are considerably smaller than commonly presumed since the work of Maurice et al. (1986), at least at the level of resolution that can be accomplished with harmonized coding for these countries. The greater total linkage strength in Germany than France at this level of educational and occupational resolution comes from compositional differences in the distribution of workers across educational outcomes and from composition differences in the occupational distribution of the workforce, not from structural differences in the connection between educational outcomes and occupations. Our use of fields of study measures as well as educational levels was important for revealing the true structure of the French-German differences. Fourth, differences in linkage strength between Germany and the U.S. are related not only to the level of within-occupation earnings inequality in both countries but also

to the structure of relative occupational wages in the two countries; net of occupational status, we find that relative full-time mean occupational earnings between Germany and the U.S. is positively related to the relative linkage strength of the occupation in the two countries. We conclude the paper with a summary of the broader research program that can be informed by the greater understanding of linkage structure provided by the analytical approach discussed in this paper.

2 Theoretical Background

In the past quarter-century, a large literature has emerged on the question of how institutional and organizational characteristics of countries, schools, and firms are related to access to positions in the labor market. Studies conducted in the 1980s highlighted the contributions of both schools and employers to training, and highlighted the contributions of both states and employers to the determination of skill and credential requirements for occupational entry. These studies demonstrated that the structure of training regimes had direct repercussions on how easily young school leavers get integrated in the labor market (Allmendinger, 1989; Maurice et al., 1986; Rosenbaum, Kariya, Settersten, and Maier, 1990, 1991). These studies also found that institutional linkages between school and work were, along with macroeconomic conditions and individual-level measures of educational attainment and other background variables, determinants of the duration of job search, the amount of unemployment, and the character of the first job. They had a persisting influence on occupational and earnings career trajectories, and they affected the stratification structure of a country along both occupational and wage dimensions. Because the strength and pattern of linkages condition the labor market consequences of specific educational outcomes, linkage structure was also identified as a cause of a country's distribution of educational outcomes and perhaps also the impact of family background characteristics on educational and labor market outcomes.

One aspect of educational systems that has appeared particularly relevant in many studies is the vocational education and training sector. Scholars have argued that in countries with extensive vocational education and training systems (with Germany as the prime example), the transition from school to work runs more smoothly than in countries where educational systems focus more on general education at the secondary and lower tertiary level. School-to-work linkages,

moreover, are generally stronger when employers are connected to schools in one sense or another (Allmendinger, 1989; Müller and Gangl, 2003a; Mayer and Solga, 2008; Rosenbaum et al., 1990; Shavit and Müller, 1998, 2000). The evidence in favor of the German apprenticeship system has aroused debates in the United States about strengthening vocational education and training by increasing employers' involvement in the community colleges (e.g., Hoffman, 2011), even as other scholars argue that vocational education lowers the odds of employment across the work career (Hanushek, Woessmann, and Zhang, 2011).

Various aspects of training regimes have been extensively studied in sociology (Allmendinger, 1989; Blossfeld, 1992; Kerckhoff, 1996; Shavit and Müller, 2006; Bol and Van de Werfhorst, 2013). Shavit and Müller (1998) summarized the important cross-national differences into four core characteristics of educational systems: (1) Whether they provide general or specific vocational education,[1] (2) Whether the education is nationally standardized,[2] (3) The extent to which the system is stratified via early tracking into different curricula with little mobility among tracks (vs. later tracking with more similar curricula and more mobility among tracks), and (4) The extent of credential inflation. These distinctions incorporate an understanding of what Maurice et al. (1986) referred to as the contrast between "qualification" spaces, which are training regimes where vocational qualifications are used to allocate persons to jobs, and "organizational" spaces, which are training regimes where education provides general skills, with vocational skills then typically learned after the onset of the work career via on-the-job training. In their book, Germany was the model of a "qualification" space, and France was the model of an "organizational" space. Shavit and Müller (1998) argued that credential inflation is a particular problem in organizational spaces where job queues consist of generally-educated applicants; in such systems, they argued, young people feel pressure to acquire more education in order to maintain a favorable position in the job queue. In contrast, they argued, the value of a credential in qualification spaces does not consist primarily in its position in the hierarchy of credentials, but instead is derived from the specific skill it represents. Shavit and Müller used these dimensions to differentiate the educational systems of thirteen countries, and they made and empirically evaluated specific predictions about

[1] General educational systems emphasize the teaching of general skills: literacy, arithmetic, general cognitive skills, basic cultural and communication skills, while specific vocational education systems focus on the teaching of particular functional tasks, e.g., the mastery of specific tools or machinery or crafts.

[2] Using Allmendinger's (1989) formulation, "the degree to which the quality of education meets that same standards nationwide."

how these dimensions affect the labor market value of education in the countries that were part of their collaborative study.

Meanwhile, the political science literature on national models of capitalism has concentrated more intensively on identifying the impacts of different institutional arrangements on broad economic dynamics. For example, it is argued that coordinated market economies, such as Germany or the Netherlands, have developed vocational educational and training (VET) systems that provide the range of specific skills required by firms in the production process. These institutions are maintained in coordinated market economies via the collaboration between state educational institutions and firms, and are backed by state-sanctioned licensing requirements (Culpepper and Thelen, 2008; Estevez-Abe et al., 2001; Iversen and Soskice, 2001). The baseline argument of this literature is that vocational education could only be an attractive option for students if workers are protected against dismissal. Employment protection legislation, although not in the interest of employers, is traded for specific skills formation in the educational system. To arrive at such joint agreements on skill formation and employment protection, coordination institutions are needed to allow for negotiations without a direct reference to issues of supply and demand in one single domain. Thelen (2004) demonstrated that vocational training systems were in fact fairly similar in Britain and Germany up to the first half of the 20th century. However, the vocational system has been successfully maintained in Germany, and not in Britain, because relevant German stakeholders were able to use these coordination mechanisms to modify the vocational training system to the changing environments. As a consequence, Germany has successfully maintained a high skill, high wage, manufacturing-centered economy (Streeck, 1991; Soskice, 1991; Hall and Soskice, 2001; Thelen, 2004).

Cross-national variation in the structure of market coordination can be seen in the cross-national variation in licensing and credential requirements. Many occupations have licensing requirements even in liberal market economies such as the U.S. and the U.K. (Weeden 2002 found that 33% of U.S. workers in the middle 1990s were in occupations that require licenses).[3] In contrast, while the German labor market makes relatively little use of formal licensing requirements,[4]

[3]More recent estimates from the 2006 Gallup survey put the number of workers in a licensed occupation at 29% (Kleiner and Krueger, 2010).

[4]Bol and Weeden (2014) estimate that only 5% of German workers are licensed using the language of article §132a of the German legal code and information from the German government on legal job protections.

it makes extensive use of credentialing requirements, apprenticeships, and unionization, particularly for occupations that require high levels of technical skills. Bol and Weeden (2014) estimate that 69% of jobs in the UK require either an intermediate certificate or a tertiary degree as compared with the 84% of jobs in Germany that require a vocational certificate or tertiary degree. The weaker reliance on collective bargaining (especially in the U.S.) and the stronger reliance on an educational system that is relatively uncoordinated with the specific skill requirements of firms – it is argued – leads to an American workforce with greater inequality in both skills and earnings and a smaller manufacturing sector.[5]

These cross-national studies recognize that training regimes have an internal, differentiated structure. This recognition notwithstanding, studies of training regimes tend toward at least *de facto* treatment of countries as relatively homogeneous units of analysis, whose features can be described in terms of a few overarching dimensions. This approach fits readily with the idea of institutional coupling between education and the economy. Hall and Soskice (2001), to take a notable example, view this coupling as central to the enduring institutional continuities that produce country-specific responses to global challenges (e.g., the growing importance of the service sector even in countries like Germany), and that create system evolution without convergence (Müller and Gangl, 2003a; Hillmert, 2008).

Despite the intellectual productivity of this approach, it runs the risk of overemphasizing internal institutional uniformity and under-appreciating the extent to which convergence, or the lack of convergence, may vary across educational outcomes or across occupations. Institutional change, in other words, takes place at the level of educational subsystems as well as at the level of the country taken as a whole. The upper tertiary education systems of western European countries, for example, have been changing in partial synchrony in response to the ministerial agreements that are collectively known as the Bologna Process. Another example is the development in Germany of broader and more theoretical elite vocational programs that link a bachelors degree with an apprenticeship in training in a workplace setting (Bosch and Charest, 2012), even as the share of firms offering apprenticeships (especially among small firms) has dropped and the differentiation of apprenticeship options has widened (Thelen and Busemeyer, 2012). A third

[5]Kleiner and Krueger (2010) found that U.S. licensing requirements had a weaker impact on within-occupation wage inequality than did unionization.

example is the continuing development in the U.S. of new professional and technical jobs, for example in information technology (e.g., network analyst or data communications analyst), in health fields (e.g., physicians assistant or skin care specialist), or in business (e.g., convention and meeting planners, cost estimators). Sometimes these new or growing labor market opportunities are accompanied by new licensing requirements (e.g., for skin care specialist), and in other cases not (e.g., for cost estimators). Patterns of hiring in the U.S. and perhaps also in other countries evolve through institutional forces other than licensing (e.g., the preference by employers for MBAs for certain jobs) that may function similarly to the set of explicitly professional degrees for these university level jobs that are used in Germany or the Netherlands (Van de Werfhorst, 2004).

As a consequence of technological, market, and institutional change, the "in-general" difference between specific education-occupation linkages across countries will mask substantial variation in the size of country differences for specific educational levels, specific fields of study, and specific occupations. In addition, in most cases, employers will be more strongly incentivized by either technical imperatives or institutional pressure –including the legal force of licensing –to hire specifically trained individuals for highly technical occupations regardless of the overall structure of the "qualification" or "organizational" space. Understanding how cross-national educational differences affect cross-national differences in inequality requires theory construction and empirical measurement at the level of specific educational levels, fields of study, and occupations, as well as at the more macro level of countries, varieties of capitalism, and training regimes. This understanding is not yet well-developed in the comparative literature on educational systems, school to work linkages, and their stratification consequences.

Arguments and research about these relationships typically have been carried out at highly aggregated levels of analysis. The economists Goldin and Katz (1998), for example, argued that rising inequality in the U.S. is explained by the failure of educational supply to keep up with the growing demand for high skilled labor, but their test for the U.S. was based on an aggregate analysis with a crude two-skill (college and non-college) operationalization of skill. The political scientists Bradley et al. (2003) and Busemeyer and Iversen (2012) analyze the impact on national-level inequality of national-level institutional features, such as union density, the centralization of collective bargaining, firm involvement in training, or public investment in vocational education. Comparative sociological approaches typically treat national institutions in terms of a few

dimensions assayed through an examination of a country's institutional features. They then use country-specific regressions to examine the outcomes of these country-level institutional variables on individual-level outcomes such as occupational prestige, wages, the number of job shifts in the early career, or youth unemployment (Allmendinger, 1989; Müller and Gangl, 2003b). The approach has been very productive, but at the same time it has abstracted away from the actual linkages between educational outcomes and occupational positions that – at a theoretical level – it contends are a central attribute of the educational-labor market institutional complex. This abstraction has created empirical paradoxes that the literature has not satisfactorily resolved to date.

For example, in a large comparative project on thirteen countries, Shavit and Müller (1998) concluded that the vocational specificity of educational systems was conducive to a smooth transition from school to work. School leavers in systems with stronger VET sectors found jobs more quickly, and graduates from vocational education were able both to avoid unskilled work and find skilled trade occupations more easily. However, while their study found support for this proposition at the country level, the expected micro-level association between educational track and labor market outcomes has been empirically elusive. Many comparative studies have not been able to distinguish between vocational and general/academic forms of education at the individual level (Gangl, 2002; Müller and Gangl, 2003a). Moreover, studies that have been able to make this empirical distinction have not found strong evidence that the VET sector is particularly good for those who had been enrolled in vocational education. For instance, Wolbers (2007), who studied the duration between school leaving and achieving one's first significant job with the EU Labor Force Survey, found that strong apprenticeship systems were particularly harmful for school leavers with no more than a lower secondary education. The job search period in countries with large dual systems was indeed reduced, but paradoxically it was reduced for graduates from upper secondary vocational, upper secondary academic, and tertiary education as well.

Summarizing, the evidence is weak on the micro-level foundation of more efficient transitions from school to work in countries with strong vocational training systems. The size of the vocational sector, and in particular the dual system, seems to be related to efficient transitions into employment, but the impact of the educational system is not confined to those who have been educated in the vocational sector, at least not when they are considered as one homogeneous group

of school leavers. To address these ambiguities, the literature needs to recognize that considerable heterogeneity may exist in the strength of linkages between qualifications and occupations within a specific country. We expect that fields of study leading to regulated occupations (such as health, education, or engineering professionals) contribute much to the linkage structure observed in a particular society. Even in weakly linked societies, such as the United States is asserted to be, clear linkages will exist between a subset of educational qualifications and occupational destinations. Earlier research that has analyzed the school-to-work linkages mostly at the aggregated (national) level has not been able to reveal this.

A more detailed and empirically rigorous analysis of school-work linkages can disaggregate the group of school leavers from upper secondary vocational education by explicitly examining linkages for specific fields of study to specific occupations. For example, it may be that the aggregate finding of more efficient transitions in countries like Germany results from a mixture of (very) strongly linked, less strongly linked, and weakly linked qualifications and occupations, which, in the aggregate, is stronger than the aggregate linkages in France or the United States. More efficient transitions in strongly developed VET systems may result not only from apprenticeships at the upper secondary level, but also at higher levels. Within the higher education system of countries with strong VET systems (e.g., Germany or the Netherlands), a second tier of professional degrees exists that is thought to link strongly to labor markets (Van de Werfhorst, 2004; Noelke et al., 2012 on Eastern Europe). But, to repeat, little systematic evidence exists on these assertions, particularly within a comparative context.

We develop an analytical framework for providing this evidence in the next section. In the process, we demonstrate its value for institutional analysis by using it to address two specific substantive questions. First, we revisit the differences in linkage structure between France and Germany that are predicted (but rarely studied empirically) from the "organization space" vs. "qualificational space" distinction of Maurice et al. (1986). Maurice et al's evidence was largely taken from only a portion (metal and petrochemical manufacturing) of the industrial distribution, and their research is now over three decades old and does not reflect changes that have taken place in the French educational system (Goux and Maurin, 1998; Ichou and Vallet, 2013). It is important, therefore, to investigate the comparative linkage structure of these two countries to determine whether the observations of Maurice et al. adequately describe the current reality.

Second, we demonstrate how an understanding of the differences between the linkage structure of the U.S. and Germany provide insights into the earnings distributions of the two countries that go far beyond the insights provided by the "dimensional" approach of the comparative stratification literature. We have two specific expectations. The first is that within-occupation earnings inequality will vary inversely with the strength of occupational linkages. Greater linkage means less educational variation, which should imply lower earnings inequality. Beyond this expectation however, we address the question of whether country differences in relative occupational earnings varies systematically with country differences in occupational linkage strength. If tighter matches between credentials and occupations produce either a more productive occupational workforce or enhance the ability of occupational incumbents to bargain collectively, the result would be higher mean earnings in that occupation than would be the case otherwise.

In the sections that follow, we first describe our analytical procedure and the category schemes and data that we use to compare France, Germany, and the U.S. We then analyze the differences in linkage structure across the three countries and use this analysis to answer the two substantive questions described above. We conclude the paper with a discussion of the broader research agenda that can potentially be illuminated by the new analytical approach.

3 Analytical strategy

We conceptualize the strength of linkages in terms of the association between school-leaving credentials and labor market position. For any given school-leaving credential, a strong linkage occurs when school leavers with that credential cluster in a relatively small number of labor market positions. When field of study is taken into account, the clustering should be even stronger. When this pattern occurs across the distribution of qualifications and fields of study, then education is tightly linked to the labor market. The most appealing measure of association for this phenomenon comes from the generalized entropy family of segregation measures (see Mora and Ruiz-Castillo, 2011 and also Theil and Finizza, 1971, Theil, 1972, and Reardon and Firebaugh, 2002). These measures are based on the concept of entropy. We refer to them as "linkage" measures below, though they are formally identical to multi-group segregation measures. It is important to keep in mind that segregation in our context implies a tighter coupling between educational cre-

dentials and the occupational structure of the labor market. In other words, a labor market that is relatively highly segregated by educational credentials is one where linkage between education and occupation is strong.

In this study, entropy can be conceptualized as the expected gain in information about someone's education by actually observing his or her education. It can be written as

$$E(P_g) = \sum_{g=1}^{G} p_g log(\frac{1}{p_g})$$

where $g = 1, ..., G$ index educational states and $P_g = \{p_1, ..., p_G\}$ is the set of probabilities of being in each of the G educational states. $E(P_g)$ is at a minimum when everyone has the same education and a maximum when all education states have the same proportion of the population. Our fundamental interest is in the change of entropy concerning education that comes from knowing one's occupation, or equivalently, the change in entropy concerning occupation that comes from knowing one's education. Entropy within occupations will generally be lower than overall entropy because the typical occupation conveys some information about the typical education of an occupational incumbent. This reduction in entropy becomes the measure of the strength of linkage, either at the aggregate level, or at the level of specific major occupational groups or major educational groupings, or at the level of individual occupations or educational levels or specific fields of study within educational levels. In particular, we focus on the Mutual Information Index (M), because of its attractive properties (Mora and Ruiz-Castillo, 2011). In this analysis, the Mutual Information Index measures the average reduction in entropy in P_g between its overall value and its value within a specific occupation, averaged over all occupations:

$$M = \sum_{j=1}^{J} p_j (E(P_g) - E(P_{g|j}))$$

where $j = 1, ...,$J indexes occupations. M can equivalently be formulated as the average reduction in entropy in the probability distribution across occupations, P_j, between its overall value and its value within a specific educational category, averaged over all education categories. We will refer to M as the linkage strength in a country.

M has the advantage of being strongly decomposable.[6] In our context, let X^k be the set of occupations within occupational major group k and let X be the set of all occupations. Then $X = X^1 \cup ... \cup X^K$. M has the property that

$$M(X) = M(\tilde{X}^1 \cup ... \cup \tilde{X}^K) + \sum_{k=1}^{K} p_k M(X^k) \tag{1}$$

where $\tilde{X}^k$ is the set of all workers in major group k treated as if they are all in a single super-occupation. This formula says that M equals the segregation of workers by education across occupational major groups plus the sum of the weighted within-major-group segregation values. This property allows us to determine the extent to which educational-occupational linkage occurs primarily at the major occupational group level or at the level of detailed occupations within major groups, and it allows us to compare the relative importance of educational levels and of fields of study within educational levels in constituting the overall structure of linkage in a country.

M has the additional advantage of being decomposable into linkage components for every specific occupation or educational category. This is important for us because it allows us to assess the contribution of each occupation and educational category to a country's overall structure of linkage. It also will allow us in future work to assess the importance of differences in the structure of linkage involving specific educational and occupational categories to cross-national differences in wage and earnings inequality. As discussed by Frankel and Volij (2011) (see also Alonso-Villar and Del Río, 2010), local segregation gives the extent to which the distribution across occupations of workers with a particular education outcome differ from the distribution across occupations of all workers.[7] Local segregation of educational outcomes (M_g) can be written as

$$M_g = \sum_j p_{j|g} ln \left(\frac{p_{j|g}}{p_j} \right) \tag{2}$$

where $p_{j|g}$ is the conditional probability of working in occupation j given that one is in educa-

[6] M divided by the educational entropy gives a measure known as H. M divided by occupational entropy gives a measure known as H^*. For our purposes, these alternative measures have the disadvantage of not being strongly decomposable both by educational categories and by occupations.

[7] In other words, the local segregation measure for any specific educational category is the expected information in the transformation of the set of marginal occupational proportions to the set of conditional occupational proportions (i.e., conditional on a worker having that specific educational level and field of study) (Mora and Ruiz-Castillo, 2009a). One can also express local segregation (M_j) in terms of the extent to which the educational distribution for workers in a given occupation differs from the educational distribution of workers in general.

tional group g, and p_j is the unconditional probability of working in j. Total linkage strength (M) can then be written as a weighted sum of these local segregation measures, i.e.,

$$M = \sum_g p_g M_g \tag{3}$$

where the weights are given by the relative size of each educational level-field category. It follows that the contribution of each specific educational category to total linkage strength is partly a consequence of the size of its local segregation score and partly a consequence of its relative share of all educational outcomes. In the substantive discussion below, we refer to local segregation as the "linkage strength" of a particular educational level-field of study combination or of a particular occupation.

The linkage strength of educational category g, i.e., M_g, is itself not a pure "margin-free" measure of linkage because its value depends on the distribution of workers across occupations. To see this, note that the ratio $p_{j|g}/p_j$ can be rewritten as the ratio of the joint probability of being in occupation j and educational category g divided by the predicted joint probability if j and g are independent of each other. This ratio is independent of the marginal distributions of either j or g. If we write this ratio as

$$\alpha_{gj} = \frac{p_{j|g}}{p_j}, \tag{4}$$

we can rewrite equation (4) as

$$p_{j|g} = p_j \alpha_{gj}$$

and therefore,

$$M_g = \sum_j p_j \alpha_{gj} ln(\alpha_{gj}). \tag{5}$$

M_g is clearly affected by the occupational distribution, because the "pure linkage" measures $\alpha_{gj} ln(\alpha_{gj})$ for each combination of educational category and occupation are summed to produce the overall linkage strength for category g (i.e., M_g) using weights equal to the relative size of each occupation.

To repeat: M is not a "margin-free" measure of linkage. Country differences in M will be influenced by country differences in the marginal distribution of educational categories, which affect the sum in equation (3), and by the marginal distribution of occupations, which affect the

sum in equation (5). However, country differences in M can be decomposed in two ways to isolate that part of M which is composition invariant by X, that part which affects the size of M solely through changes in the marginal distribution of X, and that part which is a difference in the entropy of Y across countries, where X and Y stand for educational categories and occupations, respectively (or, alternatively, occupations and educational categories, respectively)(Mora and Ruiz-Castillo, 2011). We decompose the differences in M due to educational composition invariant association (ΔN_g) and due to differences in the distribution of occupational (ΔO_g) and educational (ΔE_g) categories below. To be precise, we can write

$$M_{tk} - M_{tk\prime} = \Delta N_g + \Delta O_g + \Delta E_g \tag{6}$$

where

$$\Delta N_g = \frac{1}{2}\Delta N(P_{g.}(k)) + \frac{1}{2}\Delta N(P_{g.}(k'))$$

$$\Delta N(P_{g.}(k)) = \sum_{g=1}^{G} p_g(k) \sum_{j=1}^{J} \left\{ p_{j|g}(k) log(p_{j|g}(k)) - p_{j|g}(k') log(p_{j|g}(k')) \right\}$$

$$\Delta O_g = T_{occ}(k') - T_{occ}(k)$$

$$T_{occ}(k) = \sum_{j=1}^{J} p_j(k) log\left(\frac{1}{p_j(k)}\right) \tag{7}$$

$$\Delta E_g = \frac{1}{2}\Delta E(P_g(k)) + \frac{1}{2}\Delta E(P_g(k'))$$

$$\Delta E(P_g(k)) = \sum_{t=k,k'} \left\{ \sum_{g=1}^{G} \left(p_g(k') - p_g(k)\right) \sum_{j=1}^{J} p_{j|g}(g) log\left(p_{j|g}(k)\right) \right\}$$

where k and k' are countries, $P_g(k)$ is the distribution across educational categories for country k, $p_g(k)$ is the fraction of the population of country k is educational category g, and $p_{j|g}$ is the probability of being in occupation j given that one is in educational category g. Note that the contribution of the occupational distributions to the difference in total linkage strength is just the difference in entropy for the occupational distributions in the two countries; in general, the higher is the occupational entropy (i.e., the closer the distribution is to a uniform distribution), the greater is the linkage strength. See Mora and Ruiz-Castillo (2011) for further details.

The linkage measures defined above have statistical distributions that are described in Mora

and Ruiz-Castillo (2009b). Because our sample sizes are large, sampling error is generally not large enough to be of substantive importance. For results where sampling error is of interest, we estimate standard errors using bootstrapping.

4 Classification Schemes and Data

We analyze large labor force microdata for three countries: France, Germany, and the United States. For France, we use the *Enquête Emploi*, which is a quarterly labor force survey of 60-80,000 household members. The *Enquête Emploi* uses a rotating format, where all respondents participate in 6 quarters (1.5 years). We use all unique observations from the years 2005-2012, which means that all respondents only once appear in our sample. Our final analytical sample consists only of those who are employed between the ages of 18 and 65 and who are not full-time or part-time students. These restrictions result in an analytical sample of 222,050.

For Germany, we use the *Mikrozensus* of 2006. The *Mikrozensus* is a random sample of roughly 1% of German households with about 70% of these cases available for analysis in the anonymized scientific use file. All household members who are 15 years or older are interviewed by face-to-face interviews. We use the same sample restrictions for Germany as for France. These restrictions result in an analytical sample for Germany of 204,810.

For the United States, we use a combination of the 2009 American Community Survey (ACS) and the Survey of Income and Program Participation (SIPP) Topical Modules on Education and Training (plus core SIPP data) for the 2004 and 2008 panels. The ACS is a survey of roughly 1% of the American population and has been conducted yearly since 2005. We supplement the ACS with the SIPP because the ACS does not contain information of field of study for lower tertiary educational credentials. The SIPP panels have realized sample sizes of 35,000 or more households for each of the two panels. Using the same sample restrictions for the U.S. as for Germany and France gives an analytical sample of 1,437,933 for the United States. Since the SIPP contributes many fewer observations to the total sample size than the ACS, the SIPP weights are rescaled to align with the weights in the ACS.[8]

[8]We used the 2009 ACS because its use of the Census 2000 coding allowed a more direct conversion to ISCO-88. Because 2009 was also the depth of the recent recession, we also estimated the U.S. linkage structure with 2011 ACS data. The results using 2011 data are very similar to the results using 2009 data.

Education not only provides access to specific occupations; it also provides favorable chances to be employed at all, and this matters more during periods of economic contraction than during economic expansion. In 2006, the unemployment rate in Germany was 11%. The French unemployment averaged 8.9% over the years for our data. The U.S. unemployment rate in 2009 (when our ACS data was collected) was 9.3%. Limiting the analysis to those with an occupation produces approximately the same rate of selection in all three countries, though it should be kept in mind that we are studying linkage strength by educational categories, conditional on having a job. A next task, obviously, is to examine country variation in the impact of educational levels and fields of study on the probability of having a job, or of having a secure job, as well as country variation in the interaction between educational levels and fields of study and macroeconomic conditions on the probability of having a job or a secure job. Similarly, there are important distinctions between having a full-time job or a part-time job. There are also important distinctions between having a relatively secure job or an insecure job that is institutionalized in terms of fixed or indefinite term labor contracts in the European context, or jobs understood to be temporary in the American context (Kalleberg et al., 2000; Maurin and Postel-Vinay, 2005). It is highly desirable to analyze the variations in the structure of linkage strength with aspects of the employment contract (just as it is desirable to analyze variations in linkage strength by age or gender), but these analyses are necessarily out of scope for the present paper and are discussed as future research directions in the discussion section below. Our first objective is to understand the aggregate linkage structure for the employed work force in the three countries, and that is where we focus the initial analytical effort.

4.1 Occupation

Occupational classifications are harmonized using the three-digit International Standard Classification of Occupations (ISCO-88). All three countries use native occupational coding schemes that differ from ISCO in important respects. The French and German data, however, contain both ISCO-88 codes and native occupational codes in order to conform to European regulations. We converted U.S. Census 2000 codes into ISCO-88 codes using an existing crosswalk (Elliott and Gerova, 2005). In our analyses we nest detailed three-digit occupations (e.g., police inspectors, health professionals, primary school teachers) within 10 major occupational groups, which are de-

fined as the first digit of this classification. A listing of the major occupational groups as well as the detailed occupations in our study can be found in Tables A.3 and A.4. We began with 104, 106, and 108 detailed three-digit occupations in France, Germany and the United States, respectively, and then further harmonized the coding so that the same 90 occupational categories were used in all three countries.

4.2 Education

All comparative studies on education face the difficulty of measuring education in consistent ways cross-nationally. A substantial literature has evolved on how one can achieve maximum comparability of educational qualifications with a minimum loss of information (e.g., Müller and Karle, 1993; Ishida et al., 1995; Kerckhoff et al., 2002; Schneider, 2010). In this paper we rely on the International Standard Classification of Education 1997 (ISCED), which distinguishes vocational and general/academic forms of secondary and tertiary education (UNESCO, 2006). This variable, which we denote as 'educational level', is rather similar to the CASMIN classification of educational attainment which is used in much of the comparative work to date. However, we prefer ISCED over CASMIN as the CASMIN project did not include the United States, and hence is less suitable for comparisons including that country (Kerckhoff et al., 2002). ISCED has been used in major international surveys such as the European Social Survey, the EU-SILC, and the PISA studies. Our ISCED measure consists of 12 levels of education, which ranges from no education (0) to post BA degrees (6). Not all levels are available in all countries, but the number of available levels is 9 in Germany, France, and the U.S. The ISCED codes for France and Germany are assigned by the national statistical agencies, and for the United States we performed a conversion of U.S. categories into ISCED categories. Because of the importance of the distinction between a master and a doctoral level post-graduate degree in the United States, we separate these two levels into categories 6A and 6B. The educational information available in the German and French data do not allow a corresponding separation in these two countries, a fact that we think reflects the lesser importance of this distinction in these two countries.[9] In the analyses below, we present results based on the full set of ISCED distinctions available in the data as well as some

[9]In this paper, we employ the convention of placing category 6 German and French workers into category 6A in charts and tables that include U.S. data that and that make use of the 6A and 6B distinction.

additional collapsing of ISCED levels to achieve greater harmonization as described below (and later in the paper we consider distinctive American features such as the GED or "some college" without a credential). A summary of the ISCED levels can be found in Table A.1.

Fields of study within levels of education are also harmonized using the ISCED. We use the two digit fields of study measure, which distinguishes a maximum of 25 fields within levels, and we coded the field of study information in the data for the three countries into these fields. Examples of the two-digit ISCED fields include "Health", "Personal Services", and "Business and Administration." A complete list of all the two-digit ISCED fields of study is in Table A.2.

Our final educational measure is a combination of a specific educational level and field of study (we sometimes refer to this combination as "level-field"). If all levels had all fields, we would have 216 (9*24) different categories in our educational variable, but of course many of these combinations are non-existent (there are no fields in primary education, for example). More generally, the number of level-field combinations that are available, as well as the content of these combinations, differs across the countries under study. To give an example, in Germany one can obtain a Business and Administration qualification at the upper secondary level, whereas such a qualification is not available in the U.S. In general, we do not have information about fields of study at the secondary level in the United States because, for the most part, they do not exist.

We only include level-field combinations with at least 100 observations in order to mitigate sparseness bias that would otherwise inflate the calculated value of M. Given the size of the samples we employ, the excluded categories contain a very small portion of the working population in each country (1.03% in Germany, 0.78% in France, and 0.0% in the U.S.). Using the 100 observation threshold along with the obvious condition that the category must exist in a country in order to be included results in 74 educational categories in France, 85 categories in Germany, and 86 categories in the U.S. In each country, fields of education are nested within levels of education.

M is sensitive to sample size, which means that the calculated value of M is larger when cells are only sparsely filled. To make sure that our analyses are not affected by this, we ran our analysis on smaller randomly-drawn subsamples of the original sample, and examined how this affected M. These sensitivity analyses showed that total linkage strength only increased when the sample size was smaller than 200,000 observations with our operationalization of occupations, educational levels, and educational fields, and the "sparseness" bias only became notable (greater than 3%)

when the sample was around 30,000 or less. The sample size in each of our three countries was so large as to make sparseness bias unimportant.

5 Results

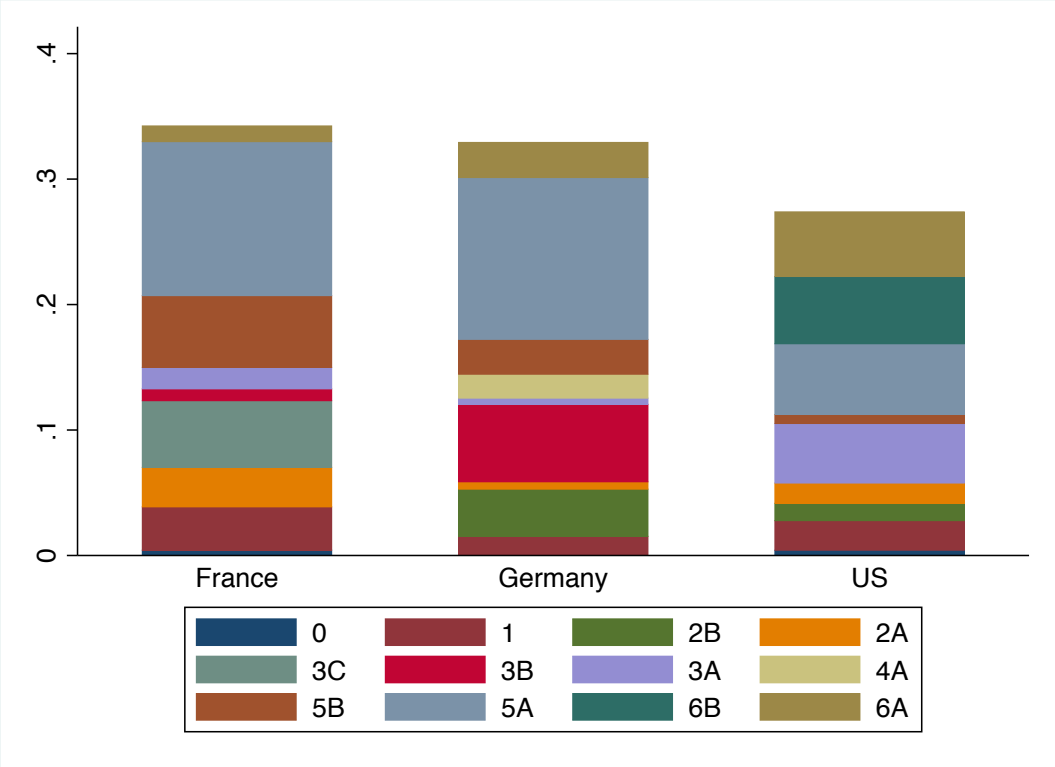
Table 1 shows the differences in the distribution across educational levels in the three countries. The main differences can be readily summarized. First, while the American lead in rates of college graduation in recent cohorts has been eroded (DiPrete and Buchmann, 2013), the U.S. continues to have a lead across all ages of the workforce in the fraction of workers who have an upper-level tertiary degree or higher. At the lower tertiary level, however, France and Germany have more degree-holders than does the U.S. Secondary school graduates are organized differently across the three countries. In the U.S., 2B and 2A correspond to high school dropouts while those with no more than a high school diploma or a GED are in 3A. Germany has 7% of its workforce coded into 4B, which are one-year programs in specialized vocational high schools. In some of the analyses below, we collapse the sub-level categories at levels 2 and 3, and we group 4A with lower tertiary (5B) in order to create greater comparability across countries.

Table 1: Distribution by Educational Level, France, Germany, and the U.S.

	Country		
Level	France	Germany	U.S.
0	0.5%	0.0%	0.8%
1	6.8%	1.8%	3.4%
2B	0.0%	8.0%	4.1%
2A	17.6%	3.2%	3.6%
3C	28.4%	0.0%	0.0%
3B	3.8%	50.4%	0.0%
3A	12.3%	2.0%	51.4%
4A	0.0%	7.2%	0.0%
5B	12.5%	10.0%	6.8%
5A	17.4%	16.0%	19.0%
6B	0.0%	0.0%	7.5%
6A	0.6%	1.3%	3.4%
Total	100%	100%	100%

We begin our analysis of linkage strength by focusing solely on the linkage characteristics of educational levels without any consideration of fields of study. Figure 1 shows that the over-

Figure 1: Linkage Strength from ISCED Education Levels Only (Ignoring Field of Study), in France, Germany, and the U.S.



all strength of linkage between educational categories and occupations (as measured by M) is roughly the same size for France and Germany, and both of these countries have somewhat higher linkage strength than the U.S. Moreover, the contribution of specific ISCED levels to overall linkage strength differs considerably by country; as we will see below, these differences stem from a combination of between-country differences in the distribution of educational levels and between-country differences in the linkage strength of levels, net of compositional differences.

We then examine the extent to which level-field combinations matter for total linkage strength. To do so, we use equation (1) to decompose total linkage strength into four terms:

A) Linkage across occupational major groups by educational levels.

B) Linkage across detailed occupations within major occupational groups by educational levels.

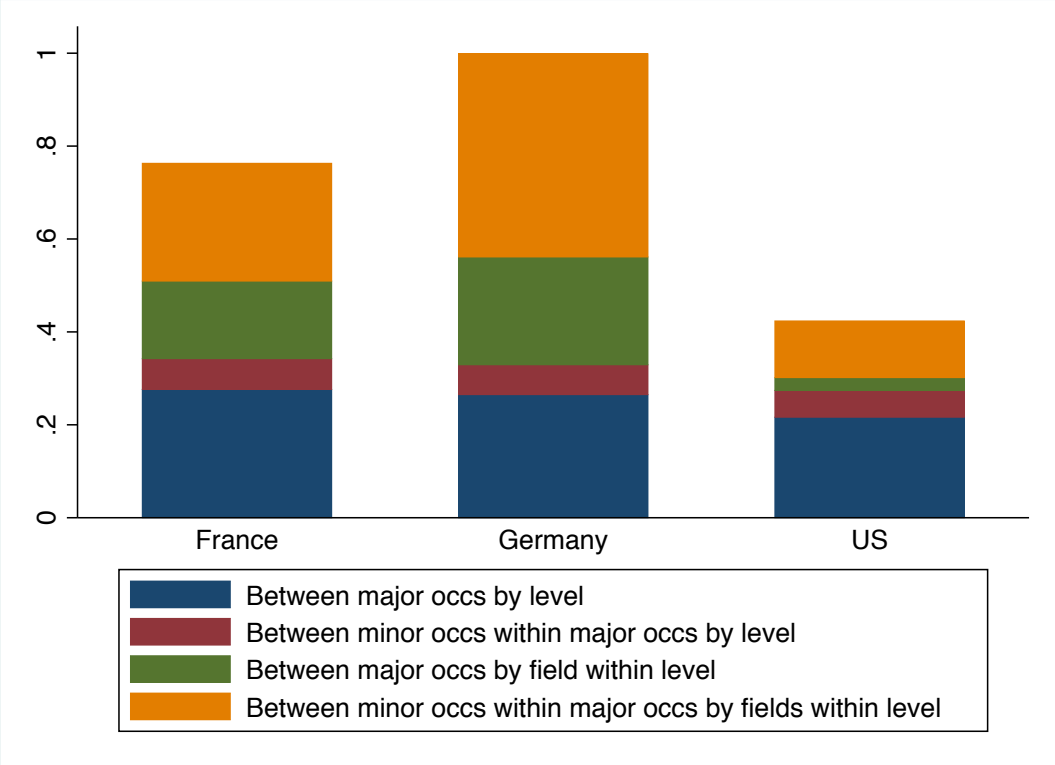
C) Linkage across occupational major groups by educational fields within levels.

D) Linkage across detailed occupations within major occupational groups by educational fields within levels.

Decomposition term A resembles most strongly the focus of the current school to work literature; it analyses the extent to which educational levels sort workers into major occupational groups, e.g., managers vs. clerical workers, or skilled manual workers vs. low-skill manual workers. Term B of the decomposition brings more detail into the occupational structure, while keeping the focus on educational levels. This term will increase if there are educational levels that sort clearly into specific occupations within major occupational groups. Decomposition term C examines the linkages between detailed educational categories and major occupational groups. The magnitude of this term illustrates the extent to which specific fields of study within levels of education sort people into particular occupational groups, for instance when lower-tertiary graduates from engineering programs are more likely to become technical workers while lower-tertiary graduates in personal services are more likely to be service/sales workers. The fourth and last term (term D) examines the contribution of specific linkages between detailed occupations and educational fields of study within educational levels. The magnitude of this linkage term depends on whether there is clear sorting from specific fields of study to specific occupations, for instance when graduates from medical school enter the occupation of medical doctor as opposed to engineer, or when the graduates from secondary school with a manufacturing qualification enter the occupation of shop assistant. The impact of these four terms on a country's total linkage strength is shown in Figure 2.

Figure 2 shows that the focus only on educational levels in Figure 1 greatly understates both the total linkage strength and the difference in linkage strength across these three countries. Fields of study contribute substantially to overall linkage, accounting for 67% of total linkage strength in Germany, 56% in France, and 35% in the U.S. When these field of study contributions are taken into account, it is evident that Germany has a much greater total linkage strength than France, and the U.S. has relatively weak total linkage strength. We see that the the ability of specific fields of study within educational levels to sort workers across occupational major groups is an important reason why M is higher in Germany and France than it is in the United States. The specific sorting consequences of fields of study, moreover, differ between Germany and France. While the sorting of fields of study into major groups contributes more to total linkage in Germany than in France, we see in Figure 2 that much of the larger linkage strength in Germany relative to France comes from the linkage of specific fields of study within educational levels to

Figure 2: Total Linkage Strength of Educational Levels and Fields of Study in France, Germany, and the U.S.

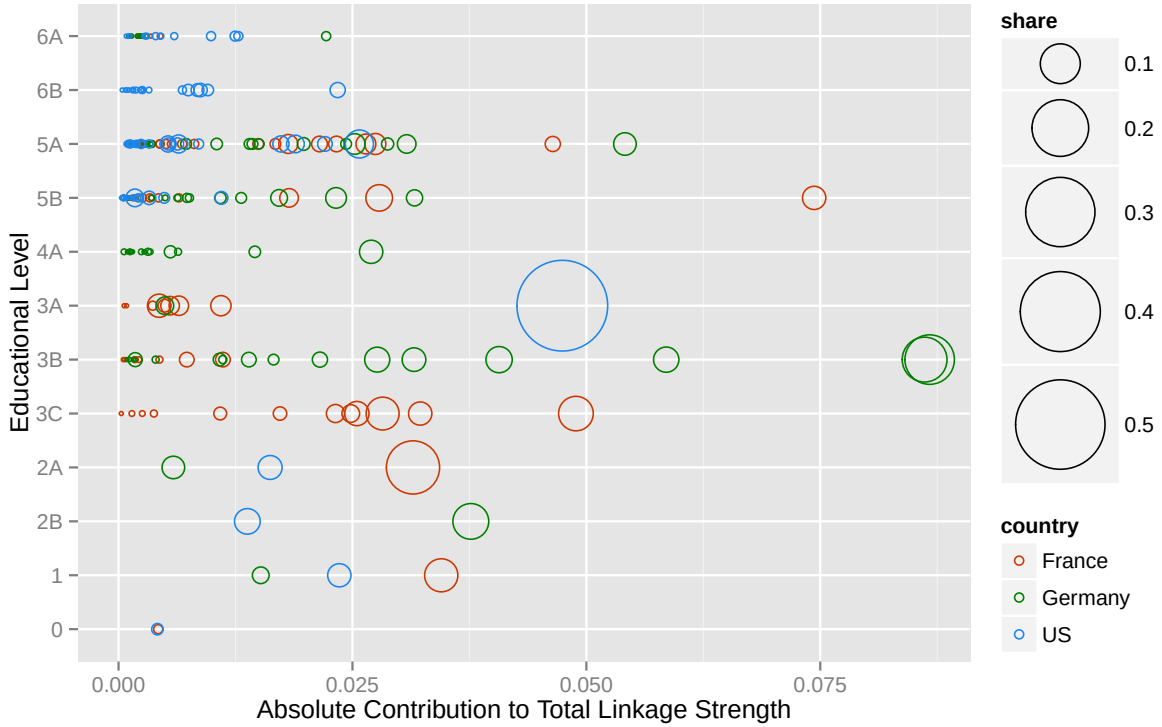


specific occupations within major occupational groups.

We also find differences among the three countries concerning the educational level where fields of study matter most. As can be seen in equation (3), the size of the contribution from each level-field combination equals the linkage strength of that level-field combination multiplied by the proportion of all workers who have that particular educational level-field of study outcome. In Figure 3, we show the size of these components for each level-field combination. The location on the X-axis shows the size of the contribution of each level-field to overall M (i.e., category linkage strength multiplied by category share in the population) and the size of the circle shows the size of the category share. For example, we can see in Figure 3 the large red circle across level 3 in the United States, which corresponds to high school completion.[10] A large share of the American workforce has only high school completion and there is no field differentiation in the American secondary school system. Consequently, the area of the level 3 circle for the U.S. is very

[10]Because we are using the ISCED harmonized scheme, we do not differentiate here between a high school diploma and a GED. We do make this distinction in a supplementary analysis for the U.S. that is reported later in the paper.

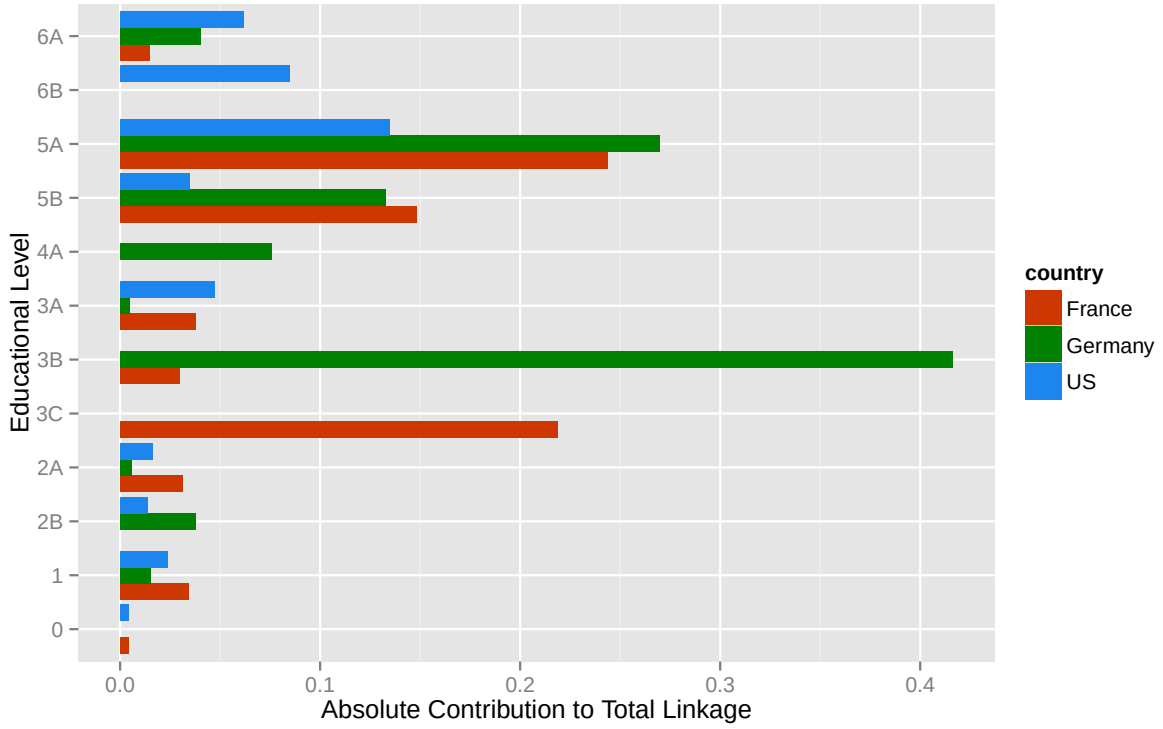
Figure 3: Contribution of Educational Level and Field of Study to Total Linkage Strength in France, Germany, and the U.S.



Note: Size of circle represents fraction of sample in the particular level-field combination. Location on the horizontal axis is the product of the linkage strength and the proportion of the population that have the specific level-field combination. U.S. educational system does not generally distinguish specific fields of study at the high school level. French and German data do not distinguish master level post-graduate degrees from doctoral level degrees.

large. At the same time, it is apparent that the relatively large contribution of high school completion to total linkage strength in the U.S. comes mainly from the large share of workers contained in this category rather than from the specific linkage strength of high school completion in the U.S., which actually and not surprisingly is very low (see Table A.7). Indeed, one can see in Figure 3 that each of three specific level-field combinations at the 3B level in Germany contribute a larger quantity to total linkage strength in Germany than does the entire population of high school graduates in the U.S., even though each of these three level-field combinations in Germany are a much smaller share of the German workforce than is the combined level 3 population in the United States. It follows that the linkage strength of these three 3B field of study categories in Germany is in each case much larger than is the linkage strength of high school graduation in the U.S., an inference that is readily confirmed in Figures A.6 and A.7.

Figure 4: Sum of Contributions of Fields of Study to Total Linkage Strength, by Educational Level and Country.



The contribution to M of specific fields of study within educational levels, which are plotted in Figure 3, can be summed within levels to show the total contribution to M of all the specific fields of study for each educational level. These total contributions, which are graphed in Figure 4, demonstrate important cross-national differences in the strength and pattern of education-occupation linkage. Fields within level 3C contribute most strongly to overall linkage strength in France, whereas 3B matters most in Germany. In the ISCED scheme, 3C represents upper secondary education not designed to lead directly to other tertiary education and 3B represents upper secondary education designed to provide direct access to vocational education at the tertiary level. Accordingly, our results seem to reflect national differences in vocational education systems, which is consistent with Shavit and Müller (1998). However, even though the school-to-work literature has in the past emphasized the importance of linkage at the secondary school level, it is clear from Figure 4 that linkage matters substantially at the tertiary level. We see strong linkages between fields of study and occupations within the lower-tertiary 5B category in both Germany and France, which confirms that linkage remains relevant beyond the space of VET and into ter-

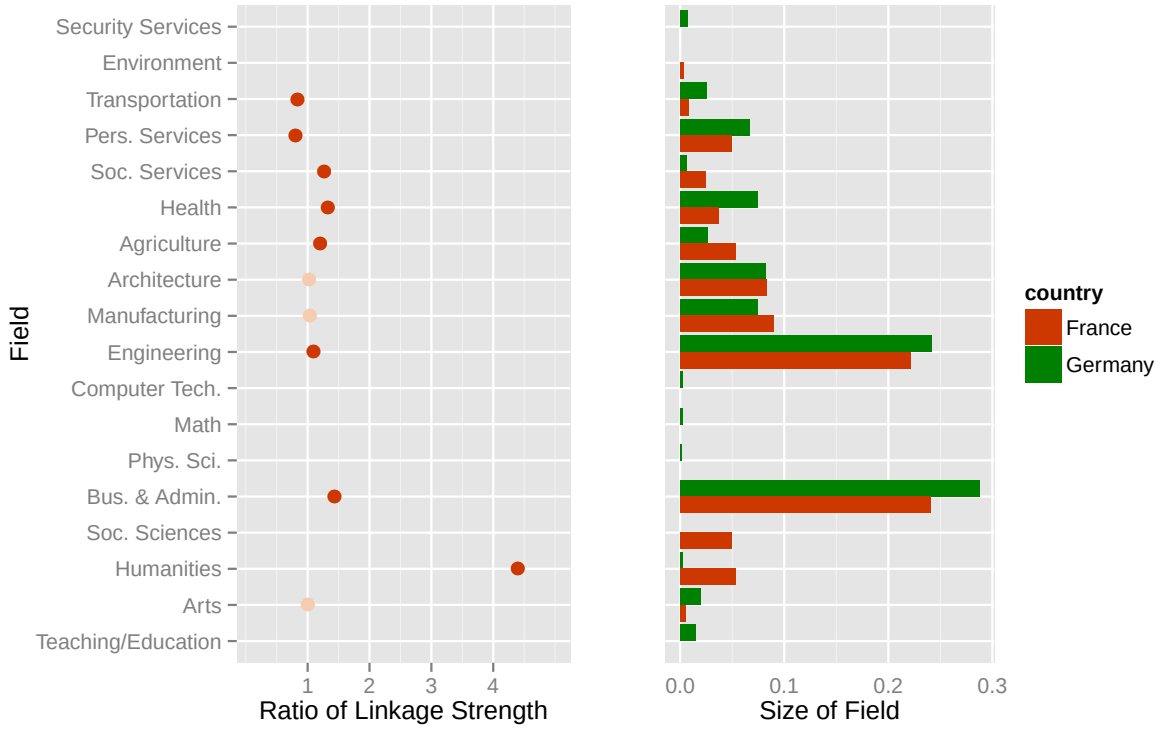
tiary education. This finding would not be visible without examining fields of study within levels of education. Figure 4 makes clear that the big difference between the U.S. and either France or Germany is at the secondary and lower tertiary educational levels. At the upper tertiary level and at the MA and doctoral level, the educational categories are contributing as much total linkage in the United States as they are in France and in Germany. This difference, as we will see below, is driven not by greater linkage strength at specific tertiary educational levels and fields of study in the U.S., but rather by the greater fraction of the workforce at these educational levels in the U.S. than in Germany or France.

We emphasize that the contribution of specific fields within levels to overall M in Figures 3 and 4 is driven partly by the strength of linkage as measured by the category linkage strength, and partly by the share of all workers who have that specific combination of educational level and field of study, which weights the category linkage strength measures to obtain the total M for a country. In Appendix Tables A.5, A.6, and A.7, we report the linkage strength for fields of study within a condensed set of educational levels for France, Germany, and the U.S. These three appendix tables show considerable variation in linkage strength across educational categories both within and between countries. As we predicted, categories that correspond well to specific occupational licensing requirements and categories at the upper tertiary level generally have rather strong linkage scores. Computing, engineering, law, architecture, business and administration, health, mathematics and statistics, and the physical sciences are all examples of fields that correspond to various professional occupations and that in almost every case have stronger linkage at the upper tertiary than at lower tertiary educational level in all three countries. At the same time, the relative linkage strength of these and other fields clearly varies across France, Germany, and the U.S.

We report the relative linkage strength and and category share in Figures 5, 6, and 7. Figure 5 shows the relative strength of linkages in France and Germany in educational levels 3 A/B/C; the U.S. is absent from this figure because the American educational system does not for the most part differentiate fields of study at this level. Figure 6 shows the relative strength of linkages for lower tertiary education (including level 4A in Germany). Figure 7 shows the relative strength of linkages for upper tertiary education, including post-graduate degrees. In each of these figures, the left-side graph shows the ratio of linkage strength in each category for the indicated country,

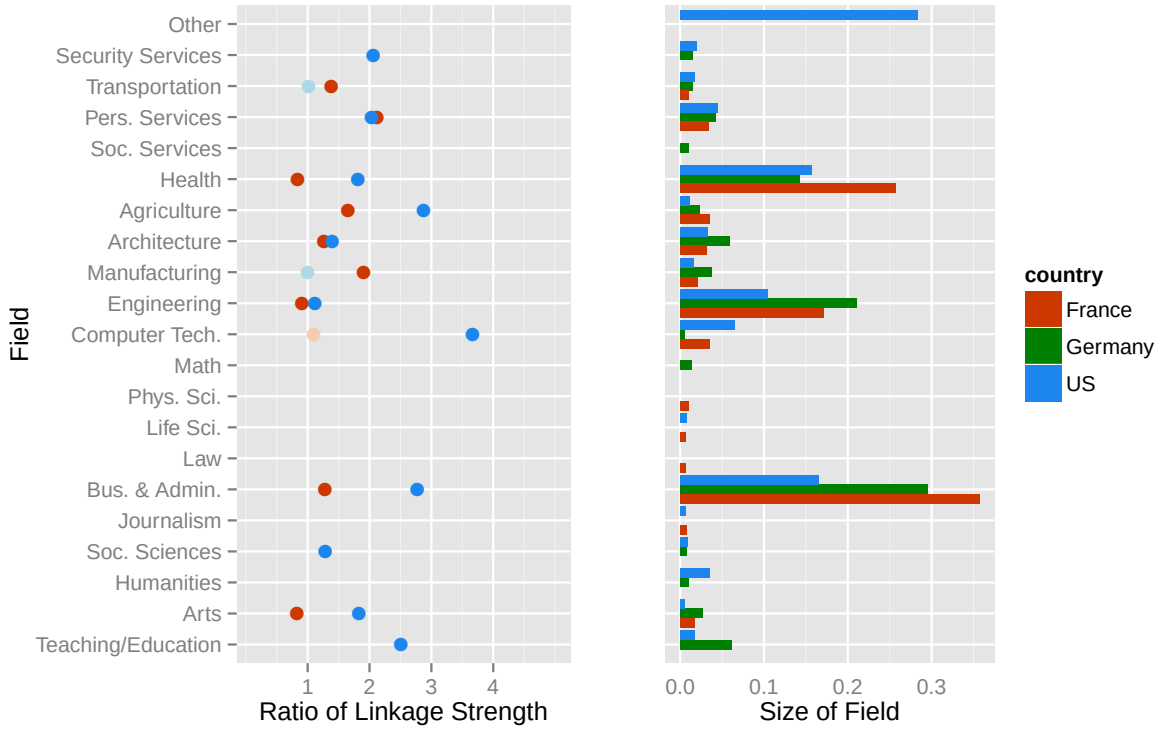
relative to Germany. A ratio greater than unity means that the German category has stronger linkage strength than does the category of the indicated country. Statistically significant differences from unity (at the 0.05 level) are shown with bold colored circles, while non-significant differences are shown with pale colored circles. The right-side graph in each case shows the distribution of workers at that educational level across the indicated level-field categories.

Figure 5: Ratio of Linkage Strength of Germany to France for Fields of Study in Secondary School, and Proportion in Fields.



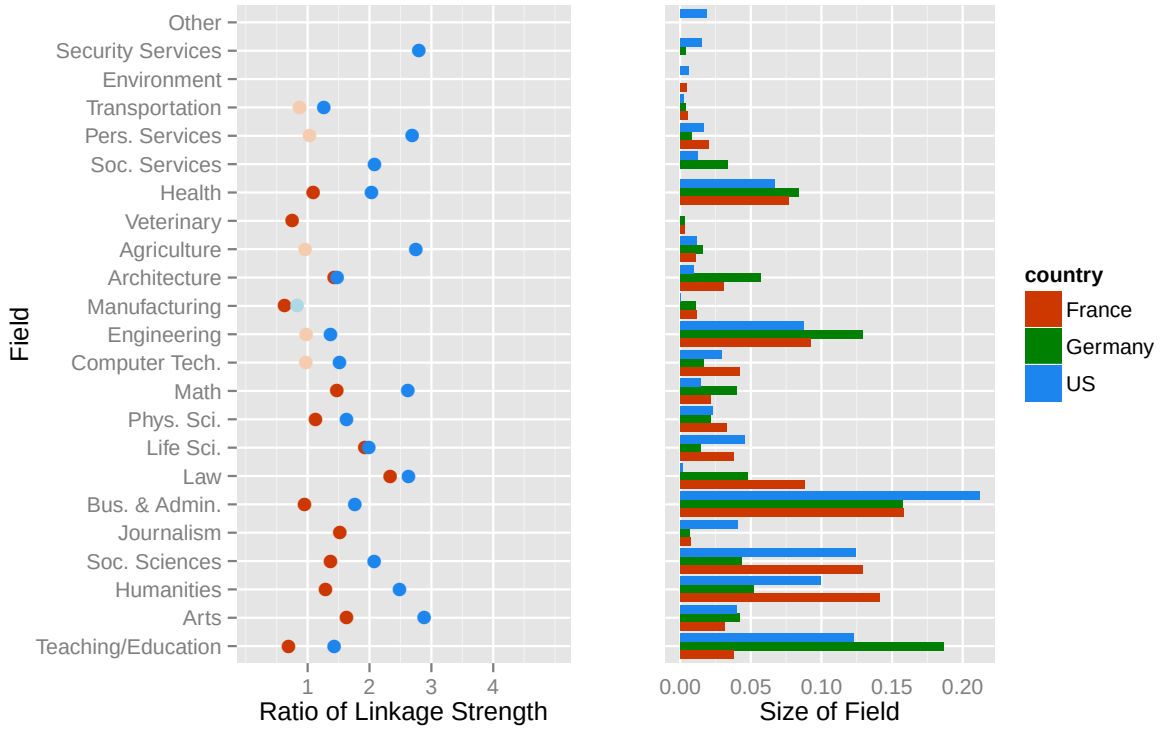
Note: A ratio of less than one means that the country has stronger linkage strength between this field and the occupational structure than does Germany. A ratio of greater than one means that the German linkage strength exceeds the linkage strength in the comparison country by the indicated amount. The light colored circles are not significantly different from a ratio of unity (standard errors were calculated using bootstrapping). The linkage strength measures that make up the ratios in the left panel are not functions of the share of the population in the educational category, which is displayed (as a proportion of the educational level) in the right panel.

Figure 6: Ratio of Linkage Strength of Germany to both France and the U.S. for Fields in Lower Tertiary (including 4A in Germany), and Proportion in Fields.



Note: A ratio of less than one means that the country has stronger linkage strength between this field and the occupational structure than does Germany. A ratio of greater than one means that the German linkage strength exceeds the linkage strength in the comparison country by the indicated amount. The light colored circles are not significantly different from a ratio of unity (standard errors were calculated using bootstrapping). The linkage strength measures that make up the ratios in the left panel are not functions of the share of the population in the educational category, which is displayed (as a proportion of the educational level) in the right panel. No ratio is shown for the "other" category, which is only present in the U.S. data.

Figure 7: Ratio of Linkage Strength of Germany to both France and the U.S. for Fields in Upper Tertiary (including Post-BA), and Proportion in Fields.



Note: A ratio of less than one means that the country has stronger linkage strength between this field and the occupational structure than does Germany. A ratio of greater than one means that the German linkage strength exceeds the linkage strength in the comparison country by the indicated amount. The light colored circles are not significantly different from a ratio of unity (standard errors were calculated using bootstrapping). The linkage strength measures that make up the ratios in the left panel are not functions of the share of the population in the educational category, which is displayed (as a proportion of the educational level) in the right panel. No ratio is shown for the "other" category, which is only present in the U.S. data.

Figure 5 shows important shared characteristics of the distribution of fields of study in France and Germany at the secondary level. In both countries, business administration and engineering are the most common fields. Among the smaller categories some differences appear; France has more secondary graduates whose field of study was in the humanities or social sciences, while relatively more of Germany's graduates were in health or personal services. In general, the linkage score for a field in Germany is slightly greater than for the corresponding field in France, though for a couple of the fields, France has tighter linkages and the two countries are very close in engineering and manufacturing.

Figure 6 shows linkage strength for lower tertiary fields of study, and this figure includes the

U.S. where – unlike the typical secondary school situation – students can specialize in different fields of study.[11] For some fields, notably engineering, the linkage strength is comparably tight in all three countries. In health and engineering – two of the most populous fields – France actually has tighter linkage than does Germany. Germany has a clear lead in the strength of linkage involving business and administration – another very populous field – over France and especially over the U.S., where linkage from this field is rather weak. The U.S. pattern is notably heterogenous, with linkages being about as strong as in France and Germany in engineering, manufacturing, and transportation, and being notably weaker in health, computer technology, and business and administration.

Figure 7 shows linkage strength for upper tertiary fields of study. The picture is one of considerable heterogeneity. Sometimes linkages in France are stronger than in Germany and sometimes they are weaker. Linkages in the U.S. are generally weaker than in either Germany or France, though the magnitude of the difference varies considerably, being relatively small in engineering, computer science, or education, and much larger in social sciences, the humanities, the arts, or health. Comparing Figures 6 and 7, one can also see that the comparative strength of linkages involving specific fields can vary across educational levels. If one compares the U.S. with either France or Germany, it is notable that the linkage gap for students with computer science degrees is much smaller at the upper tertiary level than at the lower tertiary level. The linkage gap in business and administration between the U.S. and either France or Germany similarly shrinks at the higher tertiary level. Clearly, linkage differences across these countries stem from an interaction effect between the level of education and the field of education as well as from main effects involving level and field.

[11] The SIPP – which is the source of fields of study information for lower tertiary degrees in the U.S. – provides respondents with the option of choosing "other" as their field of study, which we carry over into our analysis due to the relatively high proportion of respondents in this category.

6 Substantive Implications: Some Illustrations

6.1 Occupation Space and Organization Space: Reconsidering the Difference between France and Germany

During the 1970s, Maurice, Sellier, and Silvestre (1986) spent several years studying large metal and petrochemical manufacturing firms in France and Germany, and they concluded that the two countries differed in their structure of skills and wages. They found apprenticeship certificates to be much less common in France than in Germany. In contrast, they found university degrees to be more common in France than in Germany, particularly in management positions. Lower level white collar positions in France were differentiated from managerial positions in having neither advanced general education nor occupational training. The white collar work force in Germany, in contrast, was similar to the manual work force in being structured not so much by high levels of general education as by high levels of professional training. Whereas the level of general education sharply differentiated the managerial from the lower level white collar workforce in France, Maurice et al found very few managers in German companies holding college degrees; managers, lower level white collar workers, and foreman alike most commonly had intermediate-level professional certification.

Maurice et al concluded that in Germany, there is "a close correspondence between work force structure and the structure of occupational training (p. 11)." In France, they concluded, "training has a relatively weak influence on placement (p. 3)." Instead, they argued, "The [French] hierarchy seems to be based largely on the level of general education. In other words, there is no connection between the educational characteristics of workers and the productive structures within which they work (p. 11)." They therefore conceptualized the French labor market as an "organizational domain" in which firms "bear the major part of the burden of establishing criteria and procedures whereby work force stratification is institutionalized (p. 168)." French firms followed a common pattern of using the amount of general education of an individual as the criteria for hiring into positions of different status, with the highest positions largely reserved for the graduates of the universities and especially the *grandes écoles.* In contrast, they argued that in Germany the "professional [or qualifications] domain is paramount. This is another way of saying that work force stratification is determined by a unique standard external to each individual firm; the level

of occupational training received. (p. 168)." Maurice et. al's analysis has retained its currency in the comparative educational literature in sociology (Müller and Shavit, 1998).[12]

The argument of Maurice et al, which has persisted into the contemporary comparative stratification literature, differentiates France from Germany in two key respects. First, the distribution of young adults across educational outcomes differs in the two countries, with French workers having a higher average level of education and with a higher fraction of German workers being vocationally (or professionally) trained. The second difference is that, to quote Müller, Steinmann, and Ell (1998) (p. 4), "the association between education and jobs tends to be looser in France than in Germany." In other words, France should show weaker linkage between education and occupations than Germany, and this weaker linkage should be structural, i.e., the linkage should be typically weaker for specific educational categories rather than a consequence of compositional differences in the educational or the occupational distribution. More recently, scholars have noted important changes in the French educational system in the 1990s and 2000s, which Ichou and Vallet (2013) describe as creating a more "unified and massified" system (Ichou and Vallet 2013, Kindle location 2332), with internal stratification beginning at the end of *collège*, after which 62% of pupils are channeled into the vocational *lycée* and the remainder going on technological or academic tracks. The expansion of the French educational system has increased the pressure by higher class families to get their children admitted to *grandes écoles* (Ichou and Vallet, 2013). But the current literature has not taken cognizance of the potential impact of this expansion for school-work linkage. Our results allow a contemporary comparison of linkage structure for France and Germany.

As noted above, Germany clearly has a stronger overall education-occupation linkage than

[12]Müller and Shavit wrote that "They [Maurice et al] describe Germany as a system patterned along a *qualificational space,* while France is patterned in an *organizational space.* In Germany, vocational qualifications are used by employers to organize jobs and to allocate persons among them, whilst in France, education is less closely related to the workplace and vocational skills are mainly obtained on the job. Since organization-specific skills are often not recognized by other employers, the association between education and jobs tends to be looser in France than in Germany (Müller et al., 1998, p. 4)." Paradoxically, however, Müller and Shavit found that the effect on occupational prestige of education considered as a hierarchical variable was larger in Germany than in France, in apparent contradiction to the assertions of Maurice et al. Apparently consistent with Maurice et al., Müller and Shavit found that Germans who completed only compulsory education with no vocational training (6% of men and 14% of women who entered the labor force in 1960 or thereafter) were less likely (relative to any higher educational category) to end up in a skilled occupation than were French workers with only compulsory schooling or a lower-secondary certificate (BEPC) relative to any higher educational level. Note, however, that as recently as the 1954-58 birth cohorts, these lower categories in France held over 40% of the population (Goux and Maurin, 1998), which is much higher than the proportion for the parallel categories for Germany.

Table 2: Decomposition of the Differences in Linkage Strength from Common Educational Categories in France, Germany, and the U.S.

	Country-Difference	(Educational) Composition Invariant Linkage Difference	Occupational Entropy Contribution	Educational Distribution Contribution
	Germany-France Harmonized Educational Categories			
Germany - France	0.224	.0092	.105	.110
	Germany-France-U.S. Harmonized Educational Categories			
Germany - France	.101	-.057	.105	.053
Germany - U.S.	.210	.156	.138	-.084
France - U.S.	.109	.244	.033	-.168

does France. However, and as also discussed above in section 3, the strength of linkage is partly a function of the marginal distribution of occupations and of educational categories. The specific structural linkages of specific educational outcomes (some of which were shown in Figure 5, Figure 6, and Figure 7), moreover, do not generally seem very different between France and Germany. To address the extent to which the German advantage in total linkage strength arises from differences in composition-invariant linkage and from differences in the marginal distributions of education and occupation, we decompose country differences in M into a component that is educational composition invariant and two components that depend on country differences in the marginal distributions for education and occupation as shown in equation (6).[13] The resulting decomposition is in the top panel of Table 2.

Table 2 shows quite clearly that a central hypothesis of the "qualification space/organizational space" model is not – or at least is no longer – true. The composition-invariant linkage difference between France and Germany is now very small. The overall country difference in linkage strength now stems mainly from compositional differences between the two countries. First, the German occupational distribution is shifted relative to France towards occupations that more strongly link with educational categories. Second, the German educational distribution is shifted

[13]For greater comparability in this analysis, we collapsed together the ISCED categories "0" and "1", the lower secondary "2A" and "2B" categories, the upper secondary categories "3A," "3B," and "3C," and the lower tertiary categories "4A" and "5B."

relative to France towards educational categories that more strongly link with occupations. These compositional differences were observed by Maurice et al and were noted as an important difference in the structure of education and work in the two countries. Perhaps there were also structural differences in the strength of linkage between the countries at that time. If so, these structural differences appear to have eroded with the major changes that have taken place in the distribution of young people across educational categories and in the skill content, bargaining structure, and population distribution of occupations from the 1970s until recent years.

The field of study categorization used in our decomposition falls considerably short of the full detail of vocational and professional options in both of these countries. However, it should be pointed out that our harmonized classification goes into far greater detail than has typically been used in comparative studies of school to work transitions. These studies have typically instead emphasized hierarchical differences in education only, and have typically analyzed outcomes in terms of socioeconomic occupational scores or employment probabilities or wage outcomes without further consideration of the occupations underlying these outcomes. Our results clearly call for more detailed examination of the linkage structure between school and work in both of these countries using even more detailed native (unharmonized) measures of school-leaving credentials. While it takes greater effort to make reliable comparisons across countries using unharmonized categories, such an effort would appear to be called for in order to learn more about the French-German comparison and to confirm whether our result signifies an important evolution in these countries that requires – as our results imply – a significant re-evaluation of the accepted scholarly wisdom about their differences and similarities.

6.2 A Closer Look at Differences between the U.S. and France or Germany

The U.S. was revealed to have notably lower total linkage strength than either France or Germany. While total linkage strength for all three countries is understated by the aggregation of detailed native occupational categories into three digit ISCO harmonized categories, we can address the question of whether the use of native categories would change the ranking of the U.S. by recomputing total linkage strength using native categories. We therefore conducted a sensitivity analysis in which we substituted the 482 three digit census codes for the 90 ISCO categories used in our comparisons above. We also elaborated the American educational categories by dis-

tinguishing GED certificates from high school diplomas and by adding "some college" without a degree or certificate. Thirdly, we elaborated field of study by using all 28 field of study categories in the ACS rather than the 23 harmonized fields of study categories used above. The result of using the greater detail in the educational and occupational classifications was to raise our computed value of M from .423 to .545. While this was a 27% increase, it still is far short of the .766 computed value of M for France and the .994 value of M for Germany using the harmonized ISCO categories. We have already seen above that much of the linkage gap between the U.S. and either France or Germany stems from the lack of field of study differentiation for the large portion of the American cohorts that leave school with no more than a secondary school certificate. We can further assess the sources of the remaining country differences by suppressing all fields of study at the secondary school level and (for greater harmonization) also suppressing the distinction between 6A and 6B. The results of this decomposition are in the bottom panel of Table 2.

The bottom panel of Table 2 shows that both France and Germany have stronger linkage across educational levels and tertiary fields of study than the U.S., and this gap is primarily for structural reasons. Germany in particular also gains linkage strength relative to the U.S. because its occupational distribution is tilted towards occupations that link relatively more strongly to educational categories. However, the U.S. gains on both France and Germany from an educational distribution that favors categories that link more strongly to occupations. This is straightforward to interpret, as a greater of share of the American workforce has tertiary degrees than is true of either Germany or France, and tertiary degrees in general have stronger linkages to occupations than do secondary credentials. This distributional advantage for the U.S., however, is more than offset at the structural level; linkage is generally weaker in the U.S. than in France or Germany when comparing linkage strength for the same educational category. This summary story is readily confirmable in the pattern of linkage strength differences between the U.S. and either France or Germany that is revealed in Figures 6 and 7.

It is important to note that the analyses reported above involve the entire 18-65 year old employed workforce that is not in school. Changes in linkage structure both across the work career and over recent history – and country differences in the nature of these changes – are central aspects of what we think should be a broader research agenda around the issue of school-work linkage. Specifically with respect to the educational distribution contribution to linkage differences,

it is important to note that the American advantage in tertiary education over both France and Germany is larger across the workforce as a whole than it is for younger cohorts (DiPrete and Buchmann, 2013). Thus, we expect the nature of the decomposition in the bottom panel of Table 2 to have changed in recent history and to continue to change as the countries (especially the U.S. and France) equalize in the fraction of workers with tertiary qualifications.

6.3 Linkages and Relative Occupational Pay: A Comparison of Germany and the U.S.

A question of central interest to us concerns the implications of linkage structure for the distribution of wages and earnings and the decomposition of earnings into within- and between-occupational components. As a first step we examine the consequences of linkage structure for within occupation variance in log earnings and also for the relative mean occupational full-time earnings in Germany and the U.S. We computed the mean log earnings for full-time workers for each of the harmonized occupational categories using our analysis samples.[14] We converted German full-time earnings from Euros into dollars using purchasing power parity (PPP), but because we are using logarithmic measures, the conversion factor has no substantive influence on our results below.

First, we examine the relationship between within-occupation full-time earnings inequality (measured as the variance in log earnings) and linkage strength. Table 3 shows evidence that within-occupation earnings inequality is negatively related to the log linkage strength between educational categories and occupations. Net of occupational status, which we operationalize as the international socioeconomic index (ISEI), every percentage increase in linkage strength is associated with a reduction in the variance of log earnings by about .07% for both male and female earnings in the U.S. The relationship between linkage strength and within-occupation earnings inequality is weaker for German than for American males and the effect is not significant for German female earnings, even though the point estimate is comparable.[15] Within-occupation earn-

[14] In the ACS, the respondent's occupation is the one at which the respondent works the most hours. We operationalized full-time earnings as the per period earnings for workers in the U.S. who say that they usually work forty or more hours a week. It is possible that some of these earnings may come from second or third jobs. For the German workforce, we operationalized full time using variable F43 in the *Mikrozensus*, which asks the worker to indicate his/her status as either "*Vollzeit*" (full time) or "*Teilzeit*" (part time). The respondent reports annual earnings, measured in 24 categories.

[15] The PPP conversion factor just adds a constant to the log of German earnings (and therefore also to the mean of log earnings within occupations) and has no effect on the variance of the log earnings within occupations.

Table 3: Regression of the Within-Occupation Variance of Log Full-Time Earnings on the Log Occupational Linkage Strength.

Within-Occupation Variance of Log Full-Time Earnings								
	U.S.				Germany			
	Males		Females		Males		Females	
	Coefficient	T-Ratio	Coefficient	T-Ratio	Coefficient	T-Ratio	Coefficient	T-Ratio
Log Linkage Strength (β_1)	-.076	(-2.8)	-.051	(-2.1)	-.035	(-2.1)	-.040	(-1.0)
ISEI (β_2)	-.00047	(-0.4)	-.0022	(-2.1)	.0027	(4.0)	.0013	(0.7)
Constant	.54	(7.4)	.53	(7.8)	.11	(3.3)	.21	(2.5)
N	89		84		84		76	

Note: Observations in each regression are limited to occupations that have at least 50 full-time worker respondents of the relevant gender.

ings inequality is, from an accounting perspective, a component of total inequality, and, of course, it may also have a causal effect on the size of total inequality depending on how shifts in within-occupation earnings inequality affect a country's level of between-occupation earnings inequality.

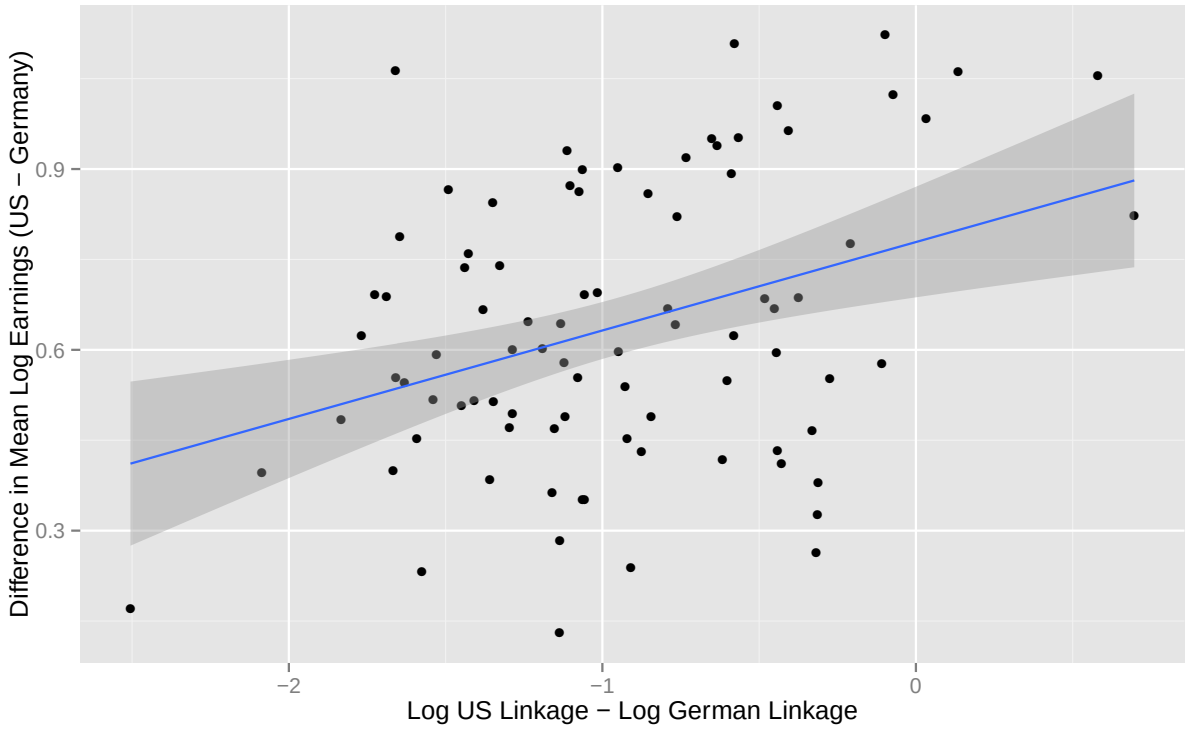
The next question is whether – at the level of the harmonized three digit ISCO-88 occupations – there is a relationship between the relative strength of linkage for a given occupation in the two countries and the relative mean full-time log earnings. In Figure 8, we present a scatterplot, where the vertical axis is the difference in the within-occupation mean log full-time earnings in the U.S. and Germany U.S.,[16] and the horizontal axis is the difference between the log linkage strength in the U.S. and in Germany.[17] The figure shows a clear positive relationship.

We show the same relationship in Table 4, net of a control for occupational status. In combination with Figure 8, this table contains three messages. First, the strong positive relationship between relative occupational earnings and relative occupational linkage is partly (but only partly) explained by the fact that occupations with stronger linkage are generally also higher status occupations in both countries (with the relationship stronger in the U.S. than in Germany).

[16]This is equivalent to the log of the ratio of the geometric means of the earnings of full-time workers in that occupation for the U.S. relative to Germany.

[17]Occupations are only shown in the figure if they have at least 50 full-time worker respondents in both the 2012 ACS and the 2006 Mikrozensus. The use of a PPP conversion produces a shift in the zero point of the vertical axis (and therefore affects the size of the intercept) but has no impact on the relative vertical distances among the observations.

Figure 8: Occupational Mean Earnings Difference between the U.S. and Germany by Difference in Linkage Strength.



Note: Observations are limited to occupations with at least 50 full-time worker respondents in both the U.S. and Germany.

Table 4, moreover, shows that the gap in mean occupational earnings in favor of the U.S. tends to be larger in occupations that have higher status scores and, correspondingly, lower in occupations with lower status scores; this relationship is true for both male and female incumbents. Third, Table 4 shows that – net of occupational status – the relative American advantage in full-time occupational earnings tends to grow in direct proportion to the relative strength of occupational linkage, both in general and specifically for the earnings of female workers. Conversely, the American advantage in mean occupation earnings is relatively small when the German advantage in linkage strength is relatively large. Further investigation shows that this relationship is driven primarily by the German linkage score; the higher is the German linkage score, the more favorable is the German-American full-time earnings ratio (net of occupational status) for both male and female workers.

The interpretation of Table 4 that we just offered emphasizes between-country differences in occupational mean log earnings. However, the interpretation can also be rephrased using the same statistical model in terms of within-country differences in mean log earnings among occupations. To see this, we express the equation underlying Table 4 for two occupations (i.e., for occupations j and j'), and then subtract one equation from the other and rearrange terms. The left side becomes the difference in mean log earnings for occupations j and j' in Germany. This difference equals the difference in mean log earnings for occupations j and j' in the U.S. plus two adjustment terms. The first adjustment term equals β_1 (see Table 4) multiplied by the country difference in the difference in log linkage strength for occupations j and j'. The second adjustment term equals β_2 multiplied by the difference in occupational status for occupations j and j'. In other words, the difference in mean log earnings for any two occupations in Germany is expected to be the difference in mean log earnings for the same two occupations in the U.S., plus an adjustment to account for the different size of status-associated between-occupation inequality in the two countries, plus a bonus if the difference in linkage strength between occupations j and j' is larger in Germany than the U.S., or a penalty if the difference is smaller.

The relationship between full-time earnings and linkage strength shown in Figure 8 and in Table 4 may or may not be causal. If it is causal, two mechanisms suggest themselves. A technical mechanism might underlie this relationship if German occupations which are especially well linked with the German educational system have workers who are generally better trained than

Table 4: Regression of the Difference in Mean Log Occupational Full-Time Earnings between the U.S. and Germany on the Difference in Log Occupational Linkage Strength between the U.S. and Germany.

	Difference in Mean Log-Earnings Difference (U.S. - Germany)					
	All Workers		Male FT Earnings		Female FT Earnings	
	Coefficient	T-Ratio	Coefficient	T-Ratio	Coefficient	T-Ratio
Difference in Log Linkage Strength (U.S. - Germany)	.092	(2.4)	.050	1.2	.15	(3.4)
ISEI	0.0062	(4.7)	.0071	(4.7)	.0061	(3.9)
Constant	-1.05	(-13.2)	-1.13	(-12.4)	-.94	(-9.8)
N	86		84		76	

Note: Observations in each regression are limited to occupations that have at least 50 cases for both countries, either in total (for the "all workers" analysis), or for the relevant gender.

their American counterparts. An institutional mechanism might underlie this relationship if occupations in which workers have relatively similar educational credentials can more effectively organize or have stronger closure mechanisms (Bol and Weeden, 2014). The relationship between occupational linkage and occupational closure is an important question for further research. In addition, the associations reported above suggest that country differences in overall wage and earnings inequality may arise in part from country differences in the size and structure of within- and between-occupational inequality.

7 Discussion and Conclusion

Employing a novel analytical approach to the study of school-to-work transitions, we have achieved greater clarity about the specific pathways that produce both between- and within-country differences in the structure of linkage between school and work. Drawing on multi-group segregation measures and in particular the Mutual Information Index (M), we have examined school-work linkages in France, Germany, and the U.S. with greater precision than past studies, incorporating fields of study and specific occupations in addition to educational levels and major occupational groups. Adding this level of detail has enabled us to see that much information is lost when more limited educational and occupational categories or scales are used to study differences between countries. We therefore propose the segregation approach as a fruitful analytical strategy to em-

ploy in international comparisons of school-to-work transitions, especially by taking advantage of its decompositional properties to examine the structure of linkages in important and informative ways.

The approach taken in this study has revealed a finding that is in line with most earlier studies: the linkage structure in Germany is much stronger than that in the United States, with France taking an intermediate position. In other words, we can better predict a worker's occupation by knowing the worker's educational level and field of study in Germany than we can in the U.S. This broad finding seems in line with earlier studies that have highlighted strong linkages in the German system, but our results are much more informative about how the stronger linkages are generated. Importantly, however, our analyses have revealed that the French position is intermediate not because its specific education to occupation linkages are generally weaker than in Germany (they are not weaker, as it turns out), but rather because its educational system and occupational distribution are shifted towards educational categories and occupations that have relatively weaker linkages. Relative to both France and Germany, the U.S., in contrast, has an educational system that is shifted towards upper tertiary degrees, where linkages are generally stronger, but the typical linkage between an educational category and the occupational structure is weaker in the U.S. than either in France or in Germany. Given that the U.S. is gradually losing its advantage in educational attainment over either France or Germany, one would predict that the overall linkage gap between the U.S. and either of these countries will grow unless this trend is offset by institutional change in structure of school-work linkages in the United States.

The results described above are of considerable importance for understanding how institutions structure labor markets in different countries. First of all, our approach enabled a much more detailed analysis of how persons with specific educational qualifications sort into specific occupational destinations. A major drawback of existing studies, from both the fields of comparative political economy and comparative sociology, is that countries are treated as homogeneous institutional environments. We demonstrated that linkage strength between educational qualifications and occupational destinations vary considerably within countries, and that analyzing this variation produces important new insights into the macro-characteristics of a country's educational system and its labor market. Some of this variation in country strength is readily predictable from a consideration of the licensing or technical requirements of certain occupations.

For educational programs that lead to specific licensed or professional occupations, the linkage level is relatively high in all three countries. Moreover, linkage strength for fields that can lead to professional occupations is generally higher at upper tertiary educational levels or in some cases is only found at the upper tertiary level.

However, the linkage approach employed in this paper goes beyond ready expectations to produce deeper insights even in these cases. For example, while engineers generally have degrees in engineering, the fraction of individuals with engineering degrees who work in engineering jobs varies across countries, and this fact and other aspects of the country's structure produces variation in linkage strength even for bachelor or higher-level engineering degrees. The approach produces important insights into macro-level country differences as well. Specifically, we have just illustrated the potential substantive importance of this deeper understanding of school-work linkage for addressing two important substantive questions, namely historical change in a country's structure of skill acquisition and wages, and country differences in the occupational structure of earnings inequality. In both cases, our approach has produced novel answers that deserve in-depth followup by other researchers.

Even those aspects of linkage structure that are well known are given brighter illumination by the new analytical approach. Consider the issue of vocational training at the secondary school level. It is of course well known that German secondary school programs are strongly differentiated by field of study and – as our results make clear – the same is true of the French educational system. While linkage scores of secondary school credentials in Germany and France are generally (though not always) lower than are the linkage scores of lower-tertiary credentials, it is notable how meaningful these vocational distinctions are in sorting secondary school educated workers into distinct occupations into the labor market in comparison with the highly diffuse occupational impact of a secondary school degree in the U.S. It is, of course, an inevitable consequence of an undifferentiated secondary school system that its graduates populate relatively low skill jobs in virtually all occupations that contain low skill jobs within them. Nonetheless, the relatively strong sorting of vocationally educated German and French secondary school students stands in sharp contrast to the diffuse paths into employment of the high school graduates in the U.S. As noted earlier, Hanushek et al. (2011) argue that undifferentiated systems like that of the U.S. may provide greater labor market flexibility and therefore better employment chances later in life than

systems that emphasize vocational qualifications. Given the extent to which employment rates fluctuate across countries in response to variations in social insurance systems and macroeconomic conditions as well as skill distributions, we view their conclusion as tentative. Clearly, however, the question of which system produces the greatest benefits over the entire work-career is an important and still open question of relevance to both scholarship and social policy.

Our approach is salient for other important research questions as well. We list here some of the most obvious connections. First, the linkage structure in a society is likely to have an impact on the distribution of educational outcomes. The utility of particular levels of education and fields of study and their institutional availability strongly influences their rate of expansion and cross-national variation in the distribution of credentials. The perceived value of specific credentials and the perceived uncertainty about this value are both potentially affected by the linkage structure of a country. Both perceived value and perceived uncertainty in turn arguably affect not only rates of entry into specific educational levels and fields of study but also the rates of persistence in these fields.

At a macro level we expect the linkage structure of a country to interact with its form of educational expansion. Educational expansion occurs not simply through the changing fraction of school leavers with tertiary credentials but also through the distribution of these credentials across tertiary levels, the distribution of fields of study within these levels and the impact of change in the proportion of tertiary graduates on the distribution of fields of study for secondary school graduates. In line with the varieties of capitalism literature, we argue that the political economy in a country affects the organization of work in such a way that specific industries grow in tandem with the provision of qualifications to cater those industries. The endogeneity of structures and distributions as explained by the political economy of a society needs further investigation within a framework of studying detailed linkages.

Third, our approach, when applied to historical data, should provide insights into the question of how linkages emerge. For example, the political economy literature has mainly interpreted the German system as a 'skills machine' (Culpepper and Finegold, 1999), and largely assumed that it is the human capital generated in education that makes for strong linkages between education and occupation (Van de Werfhorst, 2011). However, as has been recently addressed, VET systems also involve strong regulation of access to occupations, which implies that mechanisms

of occupational closure also shape the strength of linkages (Bol, 2014; Di Stasio, 2014). Further comparative research can investigate the extent to which qualifications are strongly linked to occupations for the skills they entail as opposed to institutionalized closure mechanisms that arise from broader political, economic, and cultural forces.

Fourth, our work is of importance to the scholarship on occupational "micro-classes" (Grusky and Sørensen, 1998; Weeden and Grusky, 2005). The micro-class approach emphasizes that important forms of within-group homogenization take place at the level of (detailed) occupations, rather than at the level of broad social classes as was previously assumed in class theories. Three such homogeneity-inducing mechanisms are allocation (who enters which class), social conditioning (with which group does one identify with), and the institutionalization of conditions (processes along which work is organized and rewarded) (Weeden and Grusky, 2005). It is evident that linkages between educational qualifications and occupations are key to all three mechanisms of class formation. That is, if one believes that class formation takes shape along these three processes, and that occupations are the level of disaggregation at which researchers should then focus, it is important to understand clearly how education and occupation, in detailed ways, are linked (Van de Werfhorst and Luijkx, 2010). In other words, the study of linkages may address criticisms of the occupation-oriented study of stratification made by proponents of "big class" research (Goldthorpe, 2002), by using the occupational level of analysis to better understand how educational outcomes are linked to placement in "big classes."

Fifth, the linkage structure approach can be used to analyze country differences in the impact of educational outcomes on the structure of access to and exit from part-time and contingent jobs, including temporary jobs, jobs on fixed term contracts, and jobs that are irregular in terms of work schedules. We expect that linkage strength for workers in part-time and irregular jobs to be weaker than for full-time workers in regular jobs, but the extent of this difference may vary by country as a consequence of the extent of institutionalization of part-time or various forms of irregular work. Inequalities between irregular and more regular forms of employment may partly be related to linkage strength (and related economic benefits) in some occupations rather than from the type of contract per se.

Sixth, wage and earnings inequality by gender and by race/ethnicity may be expressed partly through gender and race differences in the linkage structure of educational outcomes and occu-

pations, or of jobs differentiated both by occupation and by hours of work or the contingent or irregular character of work. For example, the comparatively high gender inequality in Germany, which is often explained in terms of its conservative 'familial' welfare state policies (DiPrete and McManus, 2000; Aisenbrey, Evertsson, and Grunow, 2009), may be manifested occupationally if German women are less able to find employment in well-linked occupations, and/or refrain from enrolling educational fields of study that link up strongly to occupational destinations. Such an explanation would illuminate processes by which welfare states and gender cultures create structural barriers to achieving gender equality. In similar fashion, immigrants and their descendants may find it difficult to find employment in well-paying, strongly linked occupations, and may therefore opt for more open, but also more disadvantaged educational and occupational careers.

Seventh, linkage structure is an important aspect of career mobility. One would expect that the strength of linkages might vary over the career. Part of this variation may arise from economic and technological change that produces trends in the industrial and occupational structure of jobs. Part of the variation may arise from institutional flexibility or barriers to occupational mobility that would induce or retard systematic changes in the relationship between years of labor force experience and the structure of linkage. Both of these influences on career mobility may in turn vary across countries as a consequence of institutional differences in linkage structure.

Lastly, the analyses presented in this paper are comparative, and we use harmonized occupational codes. When the focus is on a single country, it is almost always possible to analyze the linkage structure in greater detail than is possible in a comparative context. Single-country studies can typically investigate linkages in greater detail than we have been able to do in the rigorous comparative framework employed in this paper. Such an investigation would typically produce even more valuable insights on how institutional arrangements affect educational attainment, degree completion, wage and earnings distributions, unemployment, and patterns of career mobility. With large enough datasets and detailed information about occupations and educational outcomes including fields of study (which are obtainable in countries such as Germany, the U.S. or countries with appropriate register data such as Norway or Sweden), it becomes possible to examine linkages at a higher level of resolution. One issue of potential importance, for example, is status differences of schools within level. For example, recent studies of the U.S. suggests that the status and resources of a four-year university have an effect on earnings (Black and Smith, 2006).

The ACS does not provide a measure of four-year college prestige, though obtaining an advanced degree may be a reasonable proxy given that a correlation exists between college prestige and the attainment of an advanced degree (Zhang, 2005). In contrast, large sample data are available for whether the tertiary 5A institution in France was one of the elite *grandes écoles,* and this information can be incorporated into the framework developed in this paper. As noted earlier, studies with non-harmonized data can still be done comparatively if appropriate care is taken in the interpretation of results, and these comparisons can produce additional insight into the similarities and differences in national training regimes beyond what is revealed through research using fully harmonized data.

Aside from the several avenues for substantive research that are opened up by the segregation approach, there is also important methodological research to be done. As in almost any research project that deals with some aspect of segregation, the answers one gets will vary with the level of detail that one uses to measure categories, and this variation should be an object of research. Because the product of educational and occupational categories can be large, it is also important that systematic study be done of the data requirements for analyzing linkage at any specific level of detail. Our examination of sparseness bias suggests that sample sizes of 100,000 or more are preferable when the analysis employs category schemes with about the same level of resolution as in this paper, but these simulations need to be repeated on a broader set of countries in order to get more information about the distribution of sparseness bias as a function of sample size, category resolution, and cross-national variation in the joint distribution of workers across these categories. We hope that this initial effort will provide the foundation for an extended research agenda that uses segregation measures to arrive at a more fine-tuned comparative understanding of the school-to-work transition.

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A The Educational Systems of France, Germany, and the U.S.: A Brief Summary

The French educational system underwent a reform towards comprehensive education at the first stage of secondary education in the late 1970s, and is therefore less stratified than it used to be. Today, all students except those with special education needs enter the *collège* at around age 11-12, a comprehensive form of education that lasts four years. At the end of *collège*, however, a major branching point exists in the French schooling system, in which students enter the vocational, technological or academic track in the *lycée*. Different forms of *baccalauréat* exams exist. Although each form formally grants access to university, the transition to university is strongly stratified based on the type of *baccalauréat* that is taken. At the tertiary level, the major distinction is between regular universities and the elite *grandes écoles*, which require a stage of preparatory classes after the *baccalauréat* exam.

Despite the inclusion of a tracked upper secondary system, the French system is considered to be less vocationally specific than the German system. Even though vocational and technological *baccalauréat* exams exist, the role of employers in the design of vocational qualifications is very limited. Also at the tertiary level there is not an explicit vocational option as is the case in Germany. Standardization is very high in France, both in terms of inputs (curricular standardization, school budgets, teacher training) and outputs (centralized exams such as the *baccalauréat*).

The German educational system is highly vocationally specific, with a large dual system of school-and-work based learning. The responsibility of vocational training is delegated largely to employers. At the post-secondary phase, it is estimated that 59 percent of students enter vocational training (Neugebauer et al., 2013). A special feature concerning the vocational orientation in the German system is that a special form of vocational tertiary education exists which prepares for professions (e.g. teaching, health care, computer programming). Like the apprenticeship system, these *Fachhochschulen* are considered to produce high "skill transparency" for employers.

The German system is also strongly stratified. Pupils are situated in full comprehensive education only until grade 4 (around age 10), after which they are sorted into either of three school types, *Hauptschule*, *Realschule,* and *Gymnasium*. *Gymnasium* prepares for the *Abitur*, the university-entrance examination. Students finishing the *Hauptschule* and *Realschule*, which comprises about

two-thirds of all students (Neugebauer et al., 2013), typically enter vocational training after their secondary school. It must be said that comprehensive education is extended in the secondary schools organized as *Gesamtschulen*, although the size of this type of comprehensive education varies considerably across German states (*Länder*). The German educational system is highly standardized, although some policies are standardized at the level of the *Länder* rather than at the national level. The system of vocational training in particular is highly standardized across the nation.

The educational system in the United States is more fragmented than is the case in France or Germany. The level of standardization is therefore rather low, although forms of standardization have been implemented in the private market, such as the Standardized Aptitude Test, to deal with the lack of transparency of educational qualifications for college admissions. Stratification of the system is low in high school, because the American high school offers a comprehensive curriculum. Tracking obviously exists within schools, although the practice of whether and how students are tracked varies considerably across schools. Although these less transparent forms of tracking may exacerbate inequalities by social origin (Lucas, 1999), it seems fair to say that these forms of stratification in the American educational system do little to improve the transparency of the skills of school-leavers for prospective employers. The vocational orientation of the American system is also limited, with little employer involvement in the design of the secondary or post-secondary curriculum.

Table A.1: ISCED 1997 Educational Levels

ISCED Level	**Description**
0	Pre-primary education
1	Primary Education
2B	Lower secondary, direct access to 3C
2A	Lower secondary, access to 3A/3B
3C	Upper secondary, labor market access
3B	Upper secondary, access to 5B
3A	Upper secondary, access to 5A
4A	Preparation for entry to level 5
5B	Tertiary education, occupation specific
5A	Tertiary education, theoretical
6	Tertiary education, advanced (Germany & France)
6B	Tertiary education (U.S. Masters)
6A	Tertiary education (U.S. Ph.D.)

Table A.2: Fields of Study

0 General Programs	52 Engineering/engineering trades
14 Teaching/education	54 Manufacturing and processing
21 Arts	58 Architecture and building
22 Humanities	62 Agriculture, forestry and fishery
31 Social and behavioral science	64 Veterinary
32 Journalism and information	72 Health
34 Business and administration	76 Social services
38 Law	81 Personal services
42 Life sciences	84 Transport services
44 Physical sciences	85 Environmental protection
46 Mathematics and statistics	86 Security services
48 Computing	99 Unknown or unspecified

Table A.3: Occupation Major Groups

Managers	Skilled Trades
Professionals	Crafts
Technicians	Operational
Clerical	Low skill/Laborers
Service/Sales	Military

Table A.4: Harmonized ISCO 3-digit Occupations

11 Legislators and Senior Officials	235 Other Teaching Professionals	323 Nursing and Midwifery Associate Professionals	413 Material-Recording and Transport Clerks	613 Market-oriented Crop and Animal Producers	742 Wood treaters, Cabinet-makers, and Related Trades Workers	828 Assemblers
110 Legislators	241 Business Professionals	330 Teaching Associate Professionals	414 Library, Mail, and Related Clerks	700 Craft and Related Trade Workers	743 Textile, Garment, and Related Trades Workers	831 Locomotive-Engine Drivers and Related Workers
122 Production and Operations Department Managers	242 Legal Professionals	334 Other Teaching Associate Professionals	419 Other Office Clerks	712 Building Frame and Related Trades Workers	744 Pelt, Leather, and Shoemaking Trades Workers	832 Motor-Vehicle Drivers
123 Other Department Managers	243 Archivists, Librarians, and Information Professionals	341 Finance and Sales Associate Professionals	421 Cashiers, Tellers, and Related Clerks	713 Building Finishers and Related Trades Workers	800 Plant and Machine Operators and Assemblers	833 Agricultural and Other Mobile-Plant Operators
130 General Managers	244 Social Science and Related Professionals	342 Business Services Agents and Trade Brokers	422 Client Information Clerks	714 Painters, Building Structure Cleaners and Related Trades Workers	812 Metal-Processing Plant Operators	834 Ships' Deck Crews and Related Workers
200 General Professionals	245 Writers and Creative or Performing Artists	343 Adminis-trative Associate Professionals	510 Personal and Protective Services Workers	720 Metal, Machinery, and Related Trades Workers	813 Glass, Ceramics, and Related Plant Operators	910 Sales and Services Elementary Occupations
212 Mathe-maticians, Statisticians, and Related Professionals	246 Religious Professionals	344 Customs, Tax, and Related Government Associate Professionals	512 Housekeeping and Restaurant Services Workers	722 Blacksmiths, Tool-makers, and Related Trades Workers	815 Chemical-Processing Plant Operators	913 Domestic and Related Helpers, Cleaners, and Launderers

Table A.4, continued

214 Architects, Engineers, and Related Professionals	311 Physical and Engineering Science Technicians	345 Police Inspectors and Detectives	513 Personal Care and Related Workers	723 Machinery Mechanics and Fitters	816 Power-Production and Related Plant Operators	914 Building Caretakers, Window, and Related Cleaners
221 Life Science Professionals	312 Computer Associate Professionals	346 Social Work Associate Professionals	514 Other Personal Services Workers	724 Electrical and Electronic Equipment Mechanics and Fitters	820 Machine Operators and Assemblers	916 Garbage Collectors and Related Laborers
222 Health Professionals (except nursing)	313 Optical and Electronic Equipment Operators	347 Artistic, Entertain-ment, and Sports Associate Professionals	516 Protective Services Workers	730 Precision, Handicraft, Printing, and Related Trades Workers	822 Chemical-Products Machine Operators	921 Agricultural, Fishery, and Related Laborers
231 Higher Education Teaching Professionals	314 Ship and Aircraft Controllers and Technicians	348 Religious Associate Professionals	520 Models, Salespersons, and Demon-strators	732 Potters, Glass-makers, and Related Trades Workers	823 Rubber and Plastic Products Machine Operators	932 Manufac-turing Laborers
232 Secondary Education Teaching Professionals	321 Life Science Technicians and Related Associate Professionals	410 Office Clerks	610 Market-oriented Skilled Agricultural and Fishery Workers	734 Printing and Related Trades Workers	826 Textile-, Fur-, and Leather-Products Machine Operators	933 Transport Laborers and Freight Handlers
233 Primary and Pre-Primary Teaching Professionals	322 Modern Health Associate Professionals	412 Numerical Clerks	612 Market-oriented Animal Producers and Related Workers	740 Other Craft and Related Trades Workers	827 Food and Related Products Machine Operators	999 Missing

Table A.5: Linkage Strength by Condensed Levels and Fields in France

	0	1	2AB	3ABC	4A/5B	5A/6B/6A
No Field	0.8304	0.5152	0.1761	0.1153	0	0.8574
Teaching/Education	0	0	0	0	0	2.3938
Arts	0	0	0	1.0599	1.7369	1.2199
Humanities	0	0	0	1.2027	0	1.0529
Social and behavioral science	0	0	0	0.2504	0	0.7934
Journalism and information	0	0	0	0	1.4351	1.8904
Business and administration	0	0	0	0.3993	0.6223	0.9977
Law	0	0	0	0	1.2042	1.358
Life sciences	0	0	0	0	2.0427	1.029
Physical sciences	0	0	0	0	1.2374	1.3919
Mathematics and statistics	0	0	0	0	0	1.409
Computing	0	0	0	0	1.5778	2.117
Engineering/engineering trades	0	0	0	0.6211	0.8344	1.4928
Manufacturing and processing	0	0	0	0.6738	0.5994	1.2179
Architecture and building	0	0	0	0.9162	0.8526	1.3897
Agriculture, forestry and fishery	0	0	0	1.2460	1.0917	1.3482
Veterinary	0	0	0	0	0	3.6169
Health	0	0	0	1.1199	2.2193	3.1453
Social services	0	0	0	1.0315	0	0
Personal services	0	0	0	1.1113	0.6246	1.1682
Transportation	0	0	0	1.2170	0.9154	1.9889
Security Services	0	0	0	0	0	0
Environment	0	0	0	0.8517	0	1.1106
Unknown or unspecified	0	0	0	0	0	0

Table A.6: Linkage Strength by Condensed Levels and Fields in Germany

	1	2AB	3ABC	4A/5B	5A/6B/6A
No Field	0.84306	0.6455	0.1497	0.1598	0.5715
Teaching/Education	0	0	2.1664	1.7701	1.6520
Arts	0	0	1.0639	1.4417	1.9891
Humanities	0	0	1.2027	1.2061	1.3578
Social and behavioral science	0	0	0	0.6823	1.0877
Journalism and information	0	0	0	0	2.8803
Business and administration	0	0	0.5737	0.7949	0.9505
Law	0	0	0	0	3.1684
Life sciences	0	0	0	0	1.9819
Physical sciences	0	0	1.4704	0	1.5723
Mathematics and statistics	0	0	1.4768	1.9629	2.0744
Computing	0	0	0.8276	1.7341	2.0538
Engineering/engineering trades	0	0	0.6798	0.7569	1.4599
Manufacturing and processing	0	0	0.6996	1.1402	0.7621
Architecture and building	0	0	0.9403	1.0755	1.9878
Agriculture, forestry and fishery	0	0	1.4986	1.8034	1.2957
Veterinary	0	0	0	0	2.7178
Health	0	0	1.4860	1.8568	3.4315
Social services	0	0	1.3091	1.6119	2.5026
Personal services	0	0	0.8969	1.3240	1.2071
Transportation	0	0	1.0167	1.2631	1.7349
Security Services	0	0	2.9979	2.7632	2.4653
Environment	0	0	0	0	0
Unknown or unspecified	0	0	0	0	0

Table A.7: Linkage Strength by Condensed Levels and Fields in the United States

	0	1	2AB	3ABC	4A/5B	5A/6B/6A
No Field	0.5128	0.6856	0.7936	0.0923	0	0
Teaching/Education	0	0	0	0	0.7063	1.1543
Arts	0	0	0	0	0.7878	0.6888
Humanities	0	0	0	0	0.2376	0.5460
Social and behavioral science	0	0	0	0	0.5317	0.5230
Journalism and information	0	0	0	0	0.7144	0.5422
Business and administration	0	0	0	0	0.2869	0.5383
Law	0	0	0	0	0	1.2039
Life sciences	0	0	0	0	0.7365	0.9962
Physical sciences	0	0	0	0	0	0.9659
Mathematics and statistics	0	0	0	0	0	0.7915
Computing	0	0	0	0	0.4733	1.3556
Engineering/engineering trades	0	0	0	0	0.6784	1.066
Manufacturing and processing	0	0	0	0	1.1383	0.9153
Architecture and building	0	0	0	0	0.7681	1.3445
Agriculture, forestry and fishery	0	0	0	0	0.6273	0.4715
Veterinary	0	0	0	0	0	0
Health	0	0	0	0	1.0231	1.6867
Social services	0	0	0	0	0	1.2028
Personal services	0	0	0	0	0.6509	0.4485
Transportation	0	0	0	0	1.2439	1.3719
Security Services	0	0	0	0	1.3393	0.8809
Environment	0	0	0	0	0	0.6478
Unknown or unspecified	0	0	0	0	0.0898	0.4623