Assignment Models and Quantitative Mismatches

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Abstract

Qualitative mismatches arise when the qualifications or skills of workers, individually or in the aggregate, are different from the qualifications or skills required or specified for their jobs. This review develops the distinction between short run mismatches occurring between workers and jobs and long run aggregate mismatches that arise from shifts in supplies and demands for workers. The review provides an analysis of the incidence of qualitative mismatches in terms of regression towards the mean. Alternative explanations for wage consequences of qualitative mismatches are considered including assignment models with Nash bargaining.

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1 Introduction

Qualitative mismatches arise when the qualifications or skills of workers, individually or in the aggregate, are different from the qualifications or skills required for their jobs. Qualitative mismatches cause losses to individual workers in reduced wages, career interruptions, and reduced job satisfaction. They cause

losses to firms in reduced productivity, and to economies in restricted growth potential. As a result of these serious consequences, major research institutions have conducted studies to understand future skill needs and mismatches. For example, the Organization for Economic Cooperation and Development (OECD, 2011b, Chapter 4; see also Glenda Quintini, 2011b), the European Expert Network on Economics of Education (2008), the National Research Council (2008) and the European Centre for the Development of Vocational Training (CEDEFOP, 2010a, 2010b) have undertaken major efforts to analyze qualitative mismatches. In addition to direct consequences, qualitative mismatches are related to significant ongoing empirical labor market phenomena, including increasing inequality, technological change that favors more skilled workers, organizational change, computerization, job polarization, and globalization. Furthermore, the explanation of qualitative mismatches involves central elements of modern labor market theory, including search theory, assignment theory, human capital, and unemployment. There has been wide-ranging empirical analysis of issues related to qualitative mismatches, future skill needs, and educational and training policies, generating an extensive relevant literature.

The approach taken in this review differs from previous work by developing the distinction between short run qualitative mismatches for individual workers and employers and long run aggregate qualitative mismatches arising from changes in the quantity demanded or supplied in a category of the labor market. These two forms of qualitative mismatches are conceptually distinct and proceed from different causes and processes. Without the distinction between the two forms, a measurement of one could be mistaken for the other. The methods and data used to examine the two forms of qualitative mismatches also differ.

Short run qualitative mismatches arise as a consequence of extensive job and worker variety combined with imperfect information and frictions in the labor market that require workers and employers to engage in search to establish employment. "Search" refers to the study of how workers go about finding a job, and how firms recruit workers. When looking for a job, a worker does not know which firms would be willing to hire him or her. When the worker gets an offer from a possible employer, the worker needs to decide whether to accept the offer or continue looking. Search theory describes the optimal strategy for a worker looking for a job, and has been extended to describe how firms look for workers. Since the wage offer that a worker could get at different employers varies according to the relation between the worker's characteristics and the characteristics of the job, continued search by the worker can generate a higher wage. However, since search is costly, the worker at some point will decide to stop searching and accept a job that pays less than the maximum attainable wage. Similarly, the productivity of a worker at a particular job varies depending on the worker's characteristics, but the employer fills the job before finding the ideal worker because it would be costly to leave the job vacant for so long. As a consequence of this search, the characteristics of the worker and firm are not perfectly matched compared to the best assignment determined with perfect and costless information. These short run qualitative mismatches are an inevitable consequence of the operation of the labor market in the presence of

costly information obtained through search. Although inevitable, the short run qualitative mismatches cause losses to both workers and firms. Workers lose because they spend time unemployed, are paid less than they could potentially earn, and must perhaps engage in on-the-job search to obtain further advancement in their careers. Employers lose because a job may remain vacant until they can find someone to fill it, they may get less production from the worker than they could hope for, and the worker may leave for a better job, generating a costly separation. The extent of the losses from qualitative mismatches in the short run depends on policies that promote efficient matching. Labor market intermediaries and temporary help agencies can reduce short run qualitative mismatches by placing workers in jobs more efficiently than the rest of the labor market. Short run qualitative mismatches would arise even in the absence of the long run aggregate qualitative mismatches that are described next, and would not disappear as a result of long run adjustments in the labor market. Short run qualitative mismatches are studied by examining how the labor market assigns workers to jobs through search by workers and employers, and how qualitative mismatches arise as a consequence of the strategies of workers and employers in the presence of costly search.

In contrast, long run aggregate qualitative mismatches arise when the economy changes in a way that alters the mix of job characteristics, or the incentives for individuals to obtain education and training change in a way that alters the mix of worker characteristics. For job characteristics, the causes could be technological change, capital investments, globalization, or organizational change. For worker characteristics, the causes could be subsidies to different levels of education, quality of preparation at earlier educational levels, or private costs of education. To understand the nature of a long run aggregate qualitative mismatch, it is convenient to consider a single labor market for jobs with a particular combination of characteristics and a corresponding group of workers. A long run qualitative mismatch should be understood as a situation in which a shift in demand in this market is not balanced by a shift in supply over a longer period of time, perhaps because the changes are not fully anticipated. To the extent that the labor market responds to these imbalances through wage and other changes, long run qualitative mismatches may not show up in comparisons between individual workers and their jobs. Long run qualitative mismatches would respond to policies that anticipated changes on the demand side and promoted changes in the educational and training system that balanced the shifts in demands for skills with shifts in supplies. Long run qualitative mismatches are studied by examining the consequences of trends in economies and societies that generate shifts in demands and supplies, including technology, globalization, organization of work, and educational institutions.

As an example of the differences between short run and long run qualitative mismatches, evidence of workers overeducated for their jobs is regularly observed, while at the same time analysts conclude that there is no aggregate overeducation (Ulrich Teichler and Harald Schomburg, 2007; Stephen Machin and Sandra McNally, 2006).

Differences between short run and long run qualitative mismatches are sum-

marized below.

Table 1: Short Run and Long Run Qualitative Mismatches

	Short Run	Long Run
Causes	Costs of searching by worker or firm prevent best matches	Unbalanced shifts in supply and demand
Methods of observation and measurement	Differences in individual job and worker characteristics	Forecasts of aggregate differences in supply and demand for labor categories
Methods of analysis	Study how workers search for jobs and how firms recruit workers	Examine consequences of trends in technological and organizational change, globalization, ICT, education
Consequences	Costly search for workers and firms, losses in worker wages and lower firm output	Lost returns to worker investments in education and training, inadequate labor force for firm expansion and growth
Policies that address mismatches	Labor institutions that encourage more efficient matches, reduction in search	Adapt educational policies to anticipated changes

The relation between short run and long run qualitative mismatches can be understood using Richard Freeman's 1976 book, "The Overeducated American." In this book, Freeman describes the long run qualitative mismatch that arose in the U.S. in the 1970's as a result of the supply of college educated labor increasing more rapidly than the demand. One consequence of this long run qualitative mismatch was that many individuals with higher levels of education were unable to find jobs that required their educational preparation. That is, the long run qualitative mismatch contributed to a short run qualitative mismatch in the form of overeducation for many individuals. Nevertheless, even in the absence of any long run qualitative mismatches, short run qualitative mismatches would continue to exist because of the difficulty of finding a job without mismatches in a reasonable amount of time.

One may believe that a competitive labor market would be able to handle any qualitative mismatches, whether in the short run or in the long run.[1] In the short run, individuals may eventually resolve qualitative mismatches by changing jobs. But not all mismatches get eliminated by individuals, and there are always new

[1] Market failures in acquiring skills are examined in Alison Booth and Dennis Snower (1996). See also Amanda Pallais (2010) for inefficiencies in entry-level labor markets.

entrants who begin their labor careers with mismatches. Consideration of short run qualitative mismatches suggests changes in institutions that could reduce the levels of short run qualitative mismatches occurring at any point in time. In the long run, workers and employers that accurately foresee labor market developments would be able to avoid imbalances between supplies and demands. However, in the current episode of a long run qualitative mismatch, discussed below in Section 3, the increase in relative wages for U.S. college graduates did not generate a sufficient increase in enrollment and graduation rates to avoid the mismatch. Market forces by themselves cannot be relied upon to eliminate qualitative mismatches in either the short run or the long run.

Labor market qualitative mismatches play a central role in current debates regarding macroeconomic policy. Peter Diamond (2011, p. 1064) reacts to the following statement by Narayana Kocherlakota (2010, p. 6), President of the Federal Reserve Bank of Minneapolis:

> "What does this change in the relationship between job openings and unemployment connote? In a word, mismatch. Firms have jobs, but can't find appropriate workers. The workers want to work, but can't find appropriate jobs. There are many possible sources of mismatch—geography, skills, demography—and they are probably all at work. Whatever the source, though, it is hard to see how the Fed can do much to cure this problem. Monetary stimulus has provided conditions so that manufacturing plants want to hire new workers. But the Fed does not have a means to transform construction workers into manufacturing workers."

Diamond argues against the conclusion that structural mismatches are generating a higher level of unemployment that would not be affected by aggregate demand policies. He cites evidence (William T. Dickens, 2010; M. Elsby, B. Hobijn, A. Şahin, 2010) that most of the shift in the unemployment-vacancy relation in the current recession arises from fewer hires instead of mismatches. The next chapter, on short run disaggregated qualitative mismatches, is concerned with mismatches generated by the business cycle as well as ongoing mismatches generated by continuing frictions and inefficiencies in the labor market (see CEDEFOP, 2010b, Chapter 5, for a discussion of skill mismatches over the business cycle).

In this study, mismatches at a point in time can be regarded as arising from three sources. First, there is a level that arises from the search procedures that workers use to find jobs and employers use to find workers. This level would arise even if there were no other sources of mismatches. Second, there is a level of mismatch that arises over the course of a business cycle as a result of workers with high education and skill levels taking jobs at which they are overqualified during high unemployment, or firms hiring workers that do not meet their requirements during low unemployment. Third, there are additional mismatches that could arise if there are imbalances between supplies and demands from long run aggregate qualitative mismatches. It is possible that overqualification

at one level could cancel out some underqualification at another level, so that the three levels are not simply added together.

Qualitative mismatches lie in the background of current unemployment and business cycle theory. Whether or not these theories explain unemployment and business cycles, they do not explain much about qualitative mismatches. Qualitative mismatches impose serious costs on workers, firms and economies. Economic theory would be more useful if it moves in the direction of explaining unemployment and mismatches as they evolve together.

As a subdiscipline of labor economics, qualitative mismatches present a large array of empirical phenomena with policy implications. Nevertheles, the analytical background for qualitative mismatches has several deficiencies. By including both supply and demand factors, assignment theories are often cited as providing a better basis for qualitative mismatches than human capital or job competition theories. However, assignment theory needs to be combined with job search theory to explain how qualitative mismatches arise, and with other theories to explain how wages are determined. This survey seeks to advance qualitative mismatches as a subdiscipline by posing the relevant disciplinary questions and contributing to its analytical basis and structure.

2 Short Run Qualitative Mismatches

This section explains how mismatches can arise in a labor market even if there are no long run imbalances between supplies and demands for workers with particular skills and qualifications. The explanation lies in the underlying problem in any labor market of determining which worker should take which job. Worker actions in looking for a job, and firm actions in looking for workers, provide a solution to this problem, but the solution may not be the best possible because of difficulties in finding jobs and workers. This imperfect solution generates mismatches. The chapter begins with the basic labor market phenomena that generate mismatches, and then goes on to describe methods of observation and measurement. The section on methods of analysis provides an explanation of the wage consequences of mismatches based on economic theories. Short run consequences of mismatches are then discussed, followed by a section on policy conclusions.

2.1 Causes of short run qualitative mismatches

In a perfectly competitive labor market without frictions, an employer would know immediately which worker would be optimal for a job, and the worker could be hired immediately. No worker would want to change job, and no employer would want to change workers. Neither unemployment nor mismatches would occur in this unrealistic model of the labor market. Qualitative mismatches arise from two fundamental features of labor markets. The first is that jobs differ by the activities required to perform them, and workers differ by their capabilities and skills in performing those activities. The second feature is that

frictions prevent firms and workers from forming the same matches that would occur in a perfectly competitive labor market with complete information. With both these features present, mismatches arise.

Differences in jobs play a longstanding role in the history of economic thought. Joop Hartog relates job heterogeneity to Adam Smith's explanations of specialization and division of labor (1992, p. 18). Job differences have been documented through the analysis of job content. The Dictionary of Occupational Titles (hereafter DOT), developed for job counseling by the U.S. Department of Labor, provides descriptions of occupations in categories of data, people and things as shown in the following table (DOT information is available at www.occupationalinfo.org).

Table 2: Dictionary of Occupational Title Categories and Activities

Data	People	Things
0 Synthesizing	0 Mentoring	0 Setting Up
1 Coordinating	1 Negotiating	1 Precision Working
2 Analyzing	2 Instructing	2 Operating-Controlling
3 Compiling	3 Supervising	3 Driving-Operating
4 Computing	4 Diverting	4 Manipulating
5 Copying	5 Persuading	5 Tending
6 Comparing	6 Speaking-Signaling	6 Feeding-Offbearing
	7 Serving	7 Handling
	8 Taking Instructions-Helping	

In this system, a lower number in a category (data, people or things) is intended to be more complex and incorporate higher number work activities in the same category, although the hierarchical structure may not hold for people. For example, a worker who could perform data activity 3 (compiling), could also do computing, copying and comparing (data activities 4, 5 and 6). Of course, jobs can also differ in the specific information used in a particular occupation or industry. Now consider an unemployed worker with data level 4, people level 6 and things level 3. If the worker does not know the characteristics of a job at a firm, the job might involve, say, data level 6, people level 4, and things level 3. If the worker took this job, he or she would be overqualified for data, underqualified for people, and exactly matched for things, as shown in Table 3. The firm may not make an offer to the worker because of the worker's underqualification in the people category. The wage rate for the worker might be less than what the worker could get in another job, since the worker has more qualifications than the job requires in the data category. However, since the worker would need to continue in unemployment while searching to find a job paying more, the worker may accept a job offer in spite of the mismatch. This mismatch arises both because of the variety (heterogeneity) of worker and job characteristics, and because of the costs of searching for a better match.

Table 3: Matches and Mismatches

	Data	People	Things
Worker Qualification	4	6	3
Job Requirement	6	4	3
Matching Outcome	Overqualified	Underqualified	Exactly Matched

With both worker and job heterogeneity, a mismatch in terms of a single characteristic (for example, the worker's underqualification in the data category above) may incompletely characterize the relation between the worker and the job. If the overqualification in the people category exactly compensates for the underqualification (that is, the people skill can be substituted for the data requirement), then the mismatch will not reduce productivity. The consequences of mismatches then depend both on the substitutability among different categories of qualifications as well as on the distributions of mismatches.

Hartog (1977, 1981) uses DOT data for the demand side to model the determination of the distribution of income. The U.S. Department of Labor has supplanted DOT with the Occupational Information Network (O*NET), which provides greater detail about job content. Suzanne Tsacoumis (2007) reviews O*NET and its use in studying changes in job skills. O*NET provides information on six categories of work: worker characteristics, worker requirements, experience requirements, occupational requirements, workforce characteristics, and occupation specific information. Both DOT and O*NET are used in recent analyses of consequences of computerization (David Autor, Frank Levy and Richard Murnane, 2003, discussed in the section on methods of analysis in long run mismatches), skill-biased technological change (Daron Acemoglu and Autor, 2011, also discussed in the section on long run mismatches), the allocation of workers to jobs (Autor and Michael Handel, 2009), and job polarization. In research on tasks that goes beyond the DOT and O*NET descriptions, Michael Handel (2007) describes the survey on Skills, Technology, and Management Practices (referred to as STAMP), prepared by the Center for Survey Research at the University of Massachusetts-Boston. Among other shortcomings, Handel argues that DOT and O*NET are weak in some content areas including information technology and employee involvement practices. In addition to skill and task requirements, STAMP includes questions on supervision, autonomy and authority; computer and other technology; employee involvement; job downgrading; and job satisfaction (Handel, 2007, Table 1). The new category of employee involvement covers job rotation and cross-training; pay for skill; formal quality control program; teams activity levels, responsibilities, and decision making authority; and bonus and stock compensation. Autor and Handel (2009) describe an additional source of job information adapted from the STAMP survey, the Princeton Data Improvement Initiative (PDII) survey, which extends previous job description systems by documenting how jobs vary within occupational categories. This variation within occupations is systematically related to the gender, race and English-language proficiency of the person in the job. Autor and Handel use the information on job characteristics that vary within occupations to provide a better model to explain wage determination. Alexandra Spitz-Oener (2006) uses the German IAB/BIBB dataset to examine

changes within occupations in an analysis of rising educational demands. The 1997 British Skills Survey provides an additional source of information on job tasks (Francis Green, David Ashton, Brendon Burchell, Bryn Davies and Alan Felstead, 2000; Alan Felstead, Duncan Gallie and Francis Green, 2002).

Competences (or competencies) provide an alternative basis for determining mismatches. Competences are intended to measure how workers perform at job activities, instead of the human capital inputs such as formal education that they bring to the job. Competences could be derived from assessments of workers' job performance or by underlying capabilities such as numeracy or literacy. Major motivations for using competences are that technological change alters job requirements over time, making mismatch comparisons more difficult, and competences increase the recognition of on-the-job training and experience (Françoise Delamare Le-Deist and Jonathan Winterton, 2005, p. 28). However, although there is agreement that a unified system is desirable, different countries and institutions have pursued different systems, reducing comparability across countries.

While Table 3 provides an illustrative example of how a mismatch could arise, recruitment practices of firms suggest that comparisons of worker and job characteristics understate the complexity of their relationship. Rosalind Searle (2009; see also Searle, 2003) describes recruitment and selection as the attraction, identification and retention of staff, and she categorizes practices as falling into three paradigms. Comparison of worker knowledge, skills and ability with an employer's corresponding job requirements, as suggested by the example using Table 2, falls under the psychometric paradigm. A second paradigm for recruitment is the social process approach, in which recruitment occurs through social interaction between the applicant and the recruiting organization. During the social interaction, the applicant and organization develop a relationship based on mutual trust. A third paradigm is based on the fit between the person and organization. In this approach, the contribution of the individual to the organization depends on their interaction with the employment environment. In the second and third paradigms, the contributions of the individual to the organization depend on more than a set of knowledge, skills and ability characteristics.

The human resource literature for employers suggests several reasons why mismatches may arise as well as providing some implicit criticisms of the subject. Practical guides to hiring and recruitment (Paul Falcone, 2002; Harvard Business Essentials, 2002) suggest interviewing and other procedures that would go beyond or substitute for the psychometric approach (interviews as a selection tool are reviewed by Searle, 2003, Chapter 5). To the extent that employers include criteria from the second and third paradigms, mismatches in terms of knowledge, skills and ability are likely to arise. At the same time, the importance of social interactions and person-organization fit suggest that mismatches in terms of knowledge, skills and abilities may not fully characterize the relation between a worker and his or her job. According to Searle, the psychometric paradigm assumes that jobs can only be performed in a particular way that can be objectively quantified, and that the employer chooses workers rationally.

Instead, employers may not be fully knowledgeable or rational in choosing selection criteria or making decisions about applicants, perhaps because of group dynamics, stereotyping or bias (2003, p. 13). The psychometric paradigm also assumes that jobs are stable over time, so that selection criteria will remain relevant. Job stability is challenged by on-going technological change that alters job activities.

2.2 Observation and Measurement of Short Run Qualitative Mismatches

Mismatches can be observed and measured either from the perspective of the individual worker or firm or from the perspective of the labor market as a whole. Methods that apply to individual workers or firms are described in the next section. Studies of the operation of labor markets during the business cycle have generated a number of methods of observing mismatches, and these are considered in the second section.

2.2.1 Mismatches between Individual Workers and Jobs

Measurement The existence of a mismatch for a particular worker at his or her job can be established by direct comparison of the worker's characteristics with the job's requirements. The most common characteristic used in this comparison is formal education. A worker with more education than required is described as overeducated, and a worker with less education than required is undereducated. Treating formal education as a qualification, these workers are also described as overqualified or underqualified. Skills provide an alternative basis for the determination of a mismatch. General or specific skills are intended to reflect whether a worker can perform a particular job. Competences provide a third alternative basis. Some datasets contain information on numeracy and literacy of the worker, but in general information on competences is seldom used because of difficulties in comparing workers or countries.

Much of the extensive literature describing mismatches is based on panel survey data. For education, the respondent may be asked about their education in relation to the education required for the job. For skills, the questions may require the researcher to make an inference about whether there is a skills mismatch. For example, in the Higher Education and Graduate Employment in Europe data used by Jim Allen and Rolf Van der Velden (2001), the analyst would infer underskilling (a deficit in skills) from agreement with the statement, "I would perform better in my current job if I possessed additional knowledge and skills."

In addition to determining mismatch based on self-assessment in surveys, objective methods may be applied. Given the respondent's education, the level of education required for the job could be given by the educational level specified for the worker's occupation through an employer's job content analysis or through an occupational database such as DOT or O*NET. An additional objective method uses a descriptive parameter (for example, the average or

the mode) from the distribution of educational levels for all workers in a given worker's occupation.

One problem with these approaches is that different methods or survey questions yield different results (see CEDEFOP, 2010b, Chapter 7, and Edwin Leuven and Hessel Oosterbeek, 2011, for reviews of measurement issues). Wim Groot and Henriëtte Maassen van den Brink (2000, Table 2, p. 154) show that different definitions generate very different levels of incidence of overeducation. Groot and Maassen van den Brink (2000, 2007) also find that mismatch incidence is higher with the subjective approach based on survey panel responses. H. Battu, C. R. Belfield, and P.J. Sloane (2000) find that subjective measures identified different individuals as being overeducated, with low correlation between the measures. Dieter Verhaest and Eddy Omey (2006) compare different measures of educational mismatch with respect to how reliably they predict outcomes. Another problem is that the magnitude of a mismatch is generally not measured. Séamus McGuinness (2006, p. 399) discusses the problems introduced by heterogeneity among individuals with the same levels of education. Relative merits of the approaches have been extensively discussed in the literature.[2] CEDEFOP (2010b, Chapter 8 and Annex, p. 69) reviews proposals for data collection in Europe and lists appropriate skill mismatch questions for surveys.

Regression Towards the Mean Before discussing the extensive literature on mismatch results, it is useful to consider what to expect. Suppose matches are based on a single characteristic, for example education, and suppose that worker educational levels and job educational requirements are accurately observed. Search and recruitment procedures would generate a correlation between the education of workers and the education required in their jobs. As a result of the imperfect correlation (and assuming overlapping distributions of worker education and job requirements), some of the matches will have worker education greater than job education requirements (overeducation) and some will have worker education less than job requirements (undereducation). We would therefore expect to observe overeducation mismatches simultaneously with undereducation mismatches. The proportions of overeducation and undereducation would depend on the distributions of education among the workers and required educational levels among jobs as well as the resulting criteria used by workers and firms to determine whether a match should be formed.

Additionally, the results can be expected to exhibit regression towards the mean, illustrated in Figure 1 with worker qualifications along the horizontal axis and job requirements along the vertical axis. Suppose that the distributions of worker qualification levels and job required qualification levels are the same and that these levels are positively but not perfectly correlated in the resulting assignment. In the figure, the steeper line shows combinations of worker qualifications and job required qualifications that are equal and correspond to a match. The flatter line shows the expected job required qualification level given the

[2] See further discussions in Dolton and Vignoles, 2000, and Hartog, 2000.

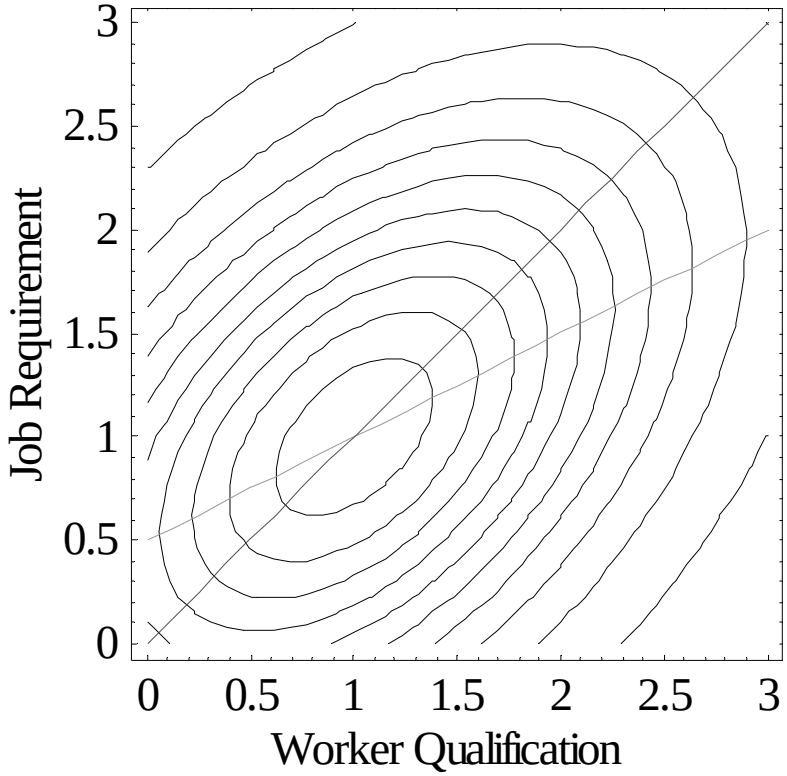

Figure 1: Job Requirements versus Worker Qualifications

worker's qualification. That is, the flatter line shows the average qualification requirement for all workers with a given qualification. For a worker with above average qualification (greater than 1), the expected job requirement would be lower than the worker's qualification level (the flatter line lies below the steeper line to the right of the intersection). Similarly, for a worker with below average qualification, the expected job qualification would be higher. As a consequence of regression towards the mean, we should therefore expect a higher incidence of overeducation or overskilling among more educated or skilled workers, and a higher incidence of undereducation or underskilling among less educated or less skilled workers.

Suppose now the horizontal axis in Figure 1 measures required job qualification, while the vertical axis measures worker qualification. At jobs with above average qualification levels (to the right of the intersection between the lines), the expected qualification level of their workers would be below their requirement level. For jobs below the average requirement level, the reverse relation would hold. From the point of view of jobs, employers with above average job

requirements are likely to experience a higher incidence of underqualification of workers, while employers with below average job requirements would experience a higher incidence of overqualification. These results are consistent with reports of hard-to-fill vacancies at employers with high levels of job requirements at times when there may be a high incidence of unemployment (Ben Casselman, 2011; Jonathan Haskel and Christopher Marin, 2001; and Manpower Group, 2011). Regression towards the mean appears in the scatter plots provided by Fabian Slonimczyk (2012, Figure 3) showing education and qualification requirements for males and females in 1973 and 2002. The figure also shows expected qualification requirement as a function of education as in Figure 1 here.

Regression towards the mean may also carry implications for wage rewards and penalties from mismatches. Suppose productivity and wages are increasing in worker qualifications and job requirements. Overqualified workers are likely to be those with above average qualifications, and underqualified workers are likely to be those with below average qualifications. With symmetric wage rewards and penalties for a unit of qualification mismatch at a given firm, the average wage penalty for overqualified workers would be greater than the average wage reward for underqualified workers.

Correlations Among Multiple Worker Characteristics What would happen if workers and jobs were described by two characteristics? Some of the mismatch literature considers the relation between educational mismatch and skill mismatch. Jim Allen and Rolf van der Velden (2001) argue that education and skill should be correlated in an assignment model. However, the relation between education and skill is unclear. It is possible that only skill is relevant to a worker's productivity in a given job, and education is an input to the determination of that skill. With this interpretation, education would be positively correlated with skill, but overeducation would not necessarily be correlated with overskilling. Alternatively, the respondents filling out a survey may view education and skill as separate contributors to their performance. Then depending on the basis for assignment, overeducation could be positively or negatively correlated with overskilling.

Consider how two types of skill would be related to each other among observed worker-job matches generated by frictional search. Suppose there are two skill categories and suppose they both contribute to productivity. The combinations of the two skills that will be observed in the labor market will be determined by how they contribute to productivity, the costs of job search and firm recruitment, and the distributions of the skills among the workforce. Under fairly general assumptions, the combinations of the two skills that yield a given level of productivity will be linearly related.[3] An isoquant of combinations of

[3] Suppose output is given by $Q = f(s_{A1}, s_{A2}, \rho)L$, where s_{A1} is the average level of the first skill, s_{A2} is the average level of the second skill, ρ is capital per worker, and L is the amount of labor. This production function has constant returns to scale in labor, capital, total amount of the first skill $s_{A1}L$, and total amount of the second skill $s_{A2}L$. The marginal productivity of a worker with a given combination of skills can be determined from the change in Q when the worker is added and will be a linear function of the worker's skills.

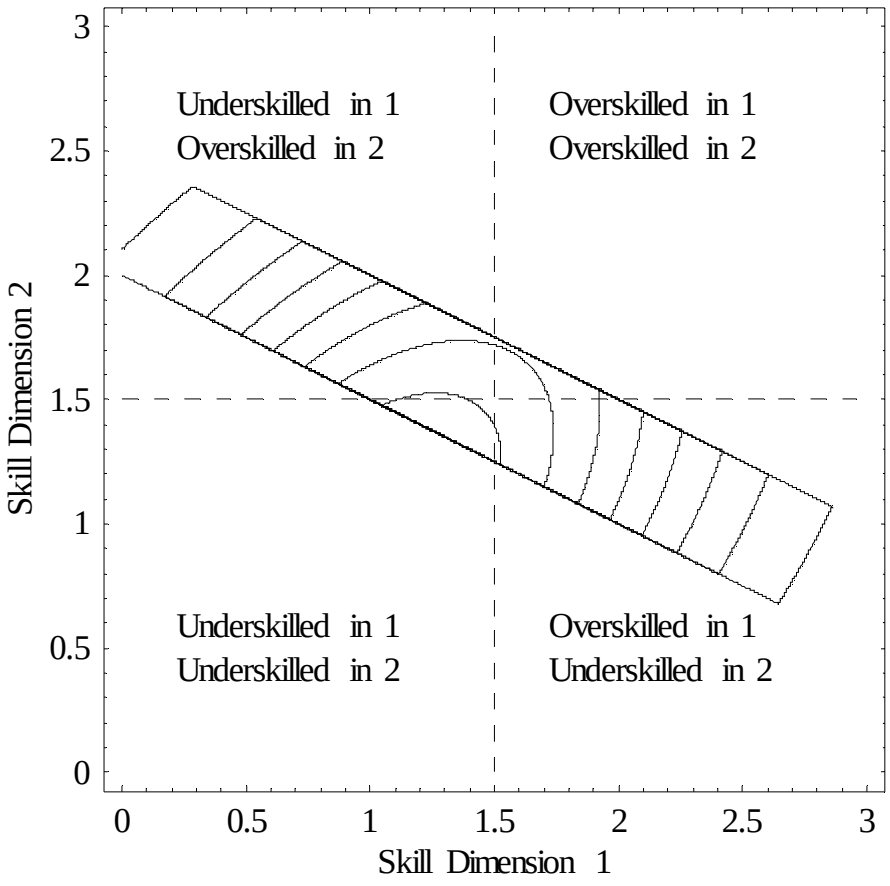

Figure 2: Negative Correlation of Skills at Firm

skills that yield a given level of productivity will then be negatively sloped, and the two skills along the isoquant will be negatively related. However, costs of search and recruitment caused by frictions lead firms to hire workers with a range of productivities for a given job. As a result, positive or negative correlations among worker skills could occur in the labor force, as illustrated in the following two examples.

In Figure 2, the two skills are moderately correlated (with correlation coefficient .5) and costs of search and recruitment are low. The figure shows matches that would occur for a firm with requirements for the first and second skills equal to 1.5. Considering recruitment costs as sunk for a given applicant, the minimum productivity of a worker offered a job is the level that leaves the firm with a loss equal to its recruitment costs. This places a lower bound on combinations of skills that the firm would find acceptable. Similarly, workers who are

too productive would choose to continue searching in hopes of finding a better match at a job with higher requirements and higher wages. This places an upper bound on the combinations of workers that would accept a job offer at the firm. Since search and recruitment costs are relatively low in this example, observed combinations fall within a narrow downward-sloping band, and the correlation between the two skills for workers employed by the firm will be negative (-.909 in this example). In this case, workers at the firm are overskilled at one skill and underskilled at the other, and relatively few are overskilled at both or underskilled at both. That is, workers who are overskilled at one of the skills are likely to be underskilled at the other.

Figure 3 presents a contrasting case, with the two skills highly correlated (with correlation coefficient equal to .9) and high costs of search and recruitment. The high correlation of skills among the workforce generates high densities of workers with skills such that the two skills are close to each other. Also, the lower bound for skill combinations is lower, because firms would rather hire workers with less productive combinations than continue recruiting, and the upper bound is higher, since workers would accept a lower wage offer for their skills rather than continue searching. As a result, the skills of workers at a given firm are positively correlated (with correlation coefficient equal to .263). Most workers at the firm are either overskilled in both dimensions or underskilled in both dimensions.

Intermediate between the cases shown in Figures 2 and 3 is the empirical result that overskilling is weakly related to overeducation, with some correlation between the two but many overeducated workers indicating underskilling and many undereducated workers indicating overskilling.

Heterogeneity Heterogeneity plays several roles in the analysis of qualitative mismatches.

- Heterogeneity generates a more difficult search problem for workers and firms, explaining why qualitative mismatches occur. With heterogeneity in worker and job characteristics, combined with incomplete information, workers must engage in search to find a match with an employer, often settling for employment with a mismatch as noted in the section on causes of short run qualitative mismatches. For example, using Table 2, suppose the activity levels are equally likely among workers and among firms. Then there would be 504 equally likely combinations of activity levels in the three categories of data, people and things (7 times 9 times 8). On average, without any information about prospective employers, a worker would find only one perfect match, with the worker's activity levels exactly equal to the job activity levels and with neither overqualification nor underqualification in each category, in 504 interviews with employers.

- Heterogeneity can generate biased statistical estimates. One source of bias is an omitted variable. Suppose an analyst is estimating a regression

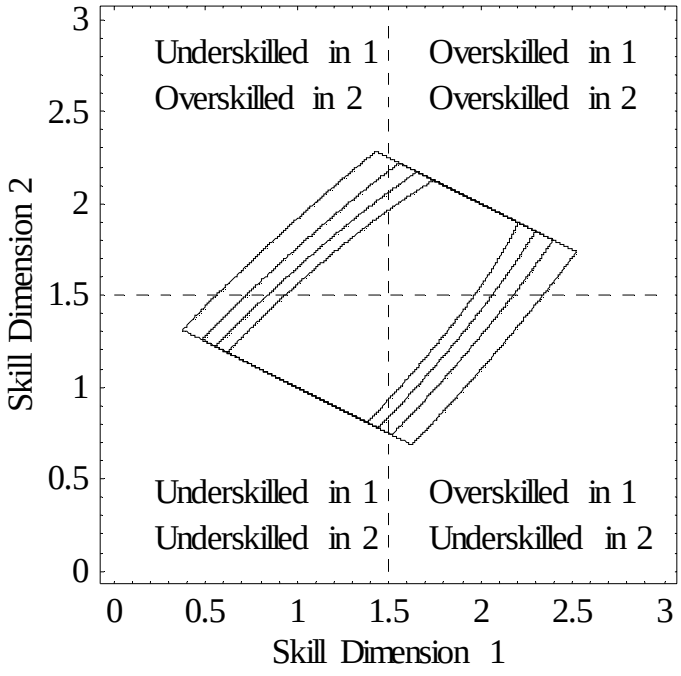

Figure 3: Positive Correlation of Skills at Firm

equation explaining the statistical determinants of an economic variable (for example, wages or job satisfaction), but one variable is unobserved by the analyst and excluded from the regression. This unobserved variable could be correlated with an observed variable, so that the coefficient of the observed variable will reflect not only its own influence but the influence of the unobserved variable. Omitted variable bias is often discussed in the context of overeducation, since unobserved ability or skill variables may influence outcomes in addition to education. For example, individuals who are overqualified may have chosen jobs where they are overqualified based on characteristics that also influence an outcome variable such as wages or job satisfaction. Finally there can be errors in the measurement of one of the independent variables (for example education in an estimate of wages). Edwin Leuven and Hessel Oosterbeek, in a survey of the overeducation literature, review omitted variable bias (2011, pp. 24-26) and measurement error (pp. 26-30) as well as econometric methods to correct for biases (see also the discussion in Sėamus McGuinness, 2006, pp. 399-401, and Tomas Korpi and Michael Tåhlin, 2009).

- Unobserved worker characteristics could substitute for observed worker characteristics, so that mismatches in terms of the observed worker characteristics would not reflect real mismatches in terms of inefficient matches. Francis Green and Steven McIntosh (2007) proposed such an argument as an alternative to actual qualitative mismatches (see the discussions of within-qualification skill heterogeneity and job heterogeneity in Quintini, 2011a, pp. 20-26, and Kostas Mavromaras and Sėamus McGuinness, 2007, p. 281). For example, workers with a given level of observed formal education may vary by unobserved ability or skills. To the extent that the ability and skills substitute for formal education, the workers could end up in jobs with different levels of formal educational requirements in spite of being appropriately matched. Heterogeneity also occurs in jobs. An occupational category may include many jobs with different requirements, but the occupation would have a single level of educational requirement determined either by the average education of workers in the occupation or by job content analysis for the occupation. This would generate apparent qualitative mismatches but not necessarily real mismatches. Support for this role of heterogeneity in individuals and jobs is that underqualified individuals have higher prose, document and quantitative scores in the International Adult Literacy Survey than well-matched individuals (OECD, 2011b, p. 202; see also Quintini, 2011a, and Beth Ingram and George Neumann, 2006). At the same time, overqualified individuals have lower scores. As a result, individuals with below average scores for their educational level may need to seek jobs with lower educational requirements, generating observed mismatches and the weak relationship between qualification and skill mismatches. However, in an analysis of Swedish data, Korpi and Tåhlin (2009) conclude that real wage consequences of mismatches remain after controlling for variations in ability.Jobs and occupa-

tions can also be heterogeneous. Within an occupation for which a single educational level is required, more difficult jobs could be filled by individuals with higher levels of education. Using 2005 data from the European Survey of Working Conditions, workers are more likely to be overqualified if they are in supervisory roles, complex jobs, jobs allowing significant independence and jobs requiring frequent use of computer skills (OECD, 2011b, p. 205; see also Quintini, 2011a).

- A worker may be hired on the basis of an observed characteristic (for example formal education), but after employment the level of an unobserved characteristic relevant to productivity will be discovered by either the worker or firm as a result of the worker's experience at the firm. No mismatches could be observed upon the worker's hire, but learning about the unobserved characteristic from employment would generate mismatches that could lead to separations, training or movement within the firm.

Several different consequences of heterogeneity can be demonstrated with the following figure, in which two correlated skills contribute to a worker's productivity. For omitted variable bias, suppose Skill 1 is observed while Skill 2 is unobserved by both the employer and the analyst. The analyst wishes to estimate the effect of Skill 1 on wages or productivity. As Skill 1 goes up, the expected Skill 2 also increases because of the correlation between the two skills. The analyst's estimate of the contribution of Skill 1 to wages or productivity is biased because the estimate includes not only the contribution of a greater value of Skill 1 but also the contribution of a greater expected value of Skill 2.

Now suppose the two skills are perfectly substitutable, with the combinations on the isoquant in Figure 4 yielding the same level of marginal productivity for the worker. Suppose both skills are observable to the employer, but only Skill 1 is observable to an analyst studying qualitative mismatches. Suppose the job requirement in terms of the observable Skill 1 is set at 1.5 for a particular employer, which with the expected level of Skill 2 yields the expected productivity along the isoquant. Then the analyst will observe substantial qualitative mismatches since Skill 1 levels will lie above and below 1.5. However, there will be no actual qualitative mismatches if all combinations of Skill 1 and Skill 2 lie along the isoquant, since all combinations will yield the same level of productivity.

Even assuming perfect substitutability between the two skills, the result is different if the employer can only discover Skill 2 after employment of the worker. Hiring would then only depend on the level of Skill 1. Suppose the employer requires a minimum Skill 1 level given by the dashed line at Skill 1 equal to 1.5. With this Skill 1 requirement, the expected productivity of the worker with Skill 1 equal to 1.5 would be determined by the expected Skill 2 level, generating the productivity given by the isoquant. After enough employment so that the employer can learn the worker's level of Skill 2, workers with combinations above the isoquant will be overqualified and workers with combinations below the isoquant will be underqualified. Qualitative mismatches will then arise in spite of the substitutability of the worker characteristics in production.

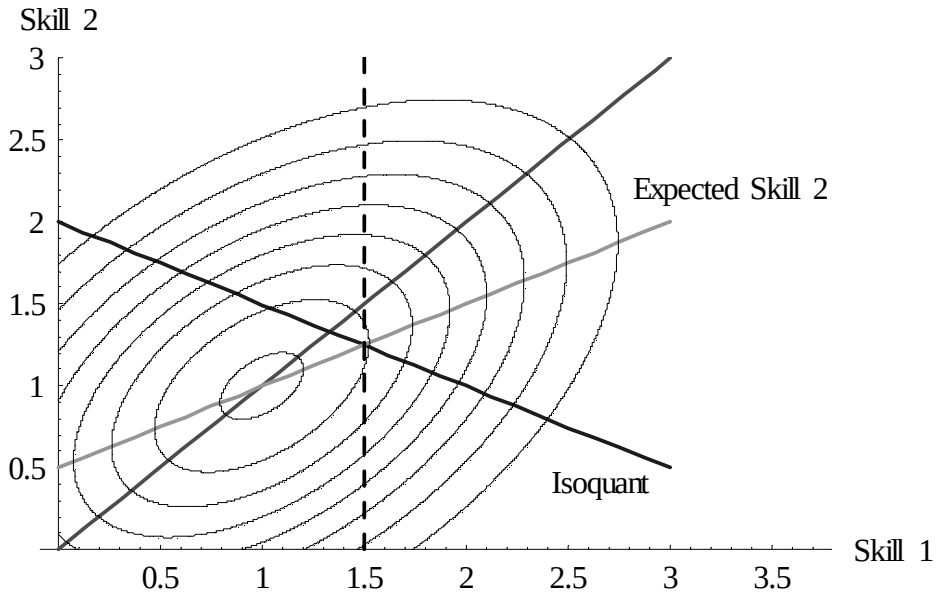

Figure 4: Heterogeneity and Qualitative Mismatches

Mismatches from Different Perspectives Separate from the questions of which characteristics or data should be used, mismatches can be defined from different perspectives based on the resulting losses:

- From a worker's perspective, a mismatch would occur if the worker would be better off in a different job that the worker could get. The literature on overeducation and undereducation, discussed in the next section, identifies the gains that workers could achieve in different jobs, if a causal interpretation can be placed on the empirical results.
- From an employer's perspective, a mismatch would occur if a different hire, at the same wage rate, would yield greater productivity. Often a firm is in the position of hiring workers with incomplete information about their productivity. Formal education may be observed, but skills, attitudes and other aspects of work habits may be unknown. A firm would only discover over time whether a mismatch occurred.
- From the economy's perspective, a mismatch would occur if the assignment of workers to jobs did not correspond to the optimal assignment. In a simple economic environment, an assignment mismatch would correspond to worker and firm mismatches if only one characteristic were relevant to productivity and employers set job requirements that corresponded to the job's requirements in an optimal assignment. Then frictional mismatch would occur simultaneously from the worker, the firm and the economy perspectives.
- From the perspective of the educational sector, a mismatch would oc-

cur if a worker were provided more education than needed to perform a job. Mismatches then raise the level of expenditure in the educational sector for a given level of production in the economy, or reduce the level of output for a given level of educational resources.

However measured, qualitative mismatches imply consequences and potential losses for workers, firms and economies.

Overeducation By far the most commonly observed form of mismatch is overeducation. Richard Freeman, in "The Overeducated American," established overeducation as a major topic of interest by describing a fundamental change in society in which workers were chronically overeducated for their jobs (1976). The prophesy was perhaps premature but generated an expanded interest in the phenomenon. Gregory Duncan and Saul Hoffman (1981) redirected inquiry away from chronic overeducation towards individual wage determination when the individual's education was greater or less than the education required for a job. They specified and estimated an extension of the Mincer earnings equation in which the wage depends on the required education for the worker's job, years of overeducation, and years of undereducation, allowing for different coefficients for the three measures. In a survey, Joop Hartog (2000) concludes that this will be a useful extension of the Mincer framework if it can be connected to more structural models of the labor market. Wim Groot and Henriëtte Maassen van den Brink (2000, 2007) conduct a meta-analysis of empirical studies of the extended Mincer equation. Their review indicates that overeducation declined over time, from 16 percent in the 1970's to 13 percent in studies using data from the 1990's. In research using Dutch data, Groot and Maassen van den Brink (2003) conclude that overeducation exhibits substantial dynamics. They conclude that mobility between jobs provides a significant mechanism to move out of a position of overeducation and that greater tenure at a given firm reduces the likelihood of being overeducated. Young workers are more likely to leave overeducation.

Edwin Leuven and Hessel Oosterbeek (2011) review the evolution of this subtopic of labor economics (see also surveys by Peter J. Sloane, 2003, Séamus McGuinness, 2006, and Peter Dolton and Oscar Marcenaro-Gutierrez, 2009). Leuven and Oosterbeek express skepticism concerning how such an estimated wage equation should be interpreted, citing different explanations provided by researchers and different policy inferences drawn. Additionally, overeducation and undereducation are calculated using different measures of required education for a job based on worker self-assessment, job analysis (for example as provided by DOT), and realized matches. Leuven and Oosterbeek report that on average (over all studies), 26 percent of workers are underschooled and 30 percent are overschooled (2011, Table 1, p. 16). Considering estimated effects of overeducation and undereducation on earnings, Leuven and Oosterbeek argue that there are extensive problems with omitted variable bias and measurement error that interfere with interpretation, and that these problems have not been resolved. Estimates of the Duncan and Hoffman earnings equation vary among

studies depending on how variables are measured and the estimation method (2011, Table 2, p. 31). The results also vary by continent, by decade, and by gender. Over all of the studies, the estimated return for required education is .089, the return for overeducation is .043, and the return for undereducation is -.036. These relative sizes are consistent with the wage predictions for regression towards the mean. The results are also consistent with human capital theory, if being overeducated for a job arises from a human capital investment opportunity that advances an individual's career, as suggested by Nachum Sicherman and Oded Galor (1990). OECD (2011b, pp. 210-211; see also Quintini, 2011a, Annex 4.A6, Table 4.A6.3) presents comparable results in terms of qualifications from European Community Household Panel data from 1994-2001 using both pooled and panel estimates. To facilitate comparisons, the following table provides the results as if there are only two levels of workers and jobs. The wage rate W11 is the wage for qualification level 1 workers in qualification level 1 jobs, while W22 is the wage rate for qualification level 2 workers in qualification level 2 jobs (with qualification level 2 being higher than qualification level 1). Table 4 presents pooled regression results from the perspective of workers.

Table 4: Wage Consequences of Qualification Mismatches from Worker Perspective

	Job Qualification Level 1	Job Qualification Level 2
Worker Qualification Level 1	W_{11}	$1.15W_{11}$
Worker Qualification Level 2	$.8W_{22}$	W_{22}

Source: OECD 2011b, pp. 210-211; Quintini, 2011a

The results show that a worker earns 15 percent more in a job where the worker is underqualified, compared to what the worker would earn with the same qualifications in a job requiring the worker's qualification level. An overqualified worker earns 20 percent less than what they would get in a job requiring their level of qualifications. These results are consistent with the wage consequences described above in the section on regression towards the mean. Table 5 makes an equivalent comparison from the perspective of jobs.

Table 5: Wage Consequences of Qualification Mismatches from Job Perspective

	Job Qualification Level 1	Job Qualification Level 2
Worker Qualification Level 1	W_{11}	$.84W_{22}$
Worker Qualification Level 2	$1.14W_{11}$	W_{22}

Source: OECD 2011b, pp. 210-211; Quintini, 2011a

In this comparison, an overqualified worker at a job with qualification level 1 would earn 14 percent more than a well-matched co-worker at the same job, while an underqualified worker at a job with qualification level 2 would earn 16 percent less than a well-matched co-worker at the same job. The effects

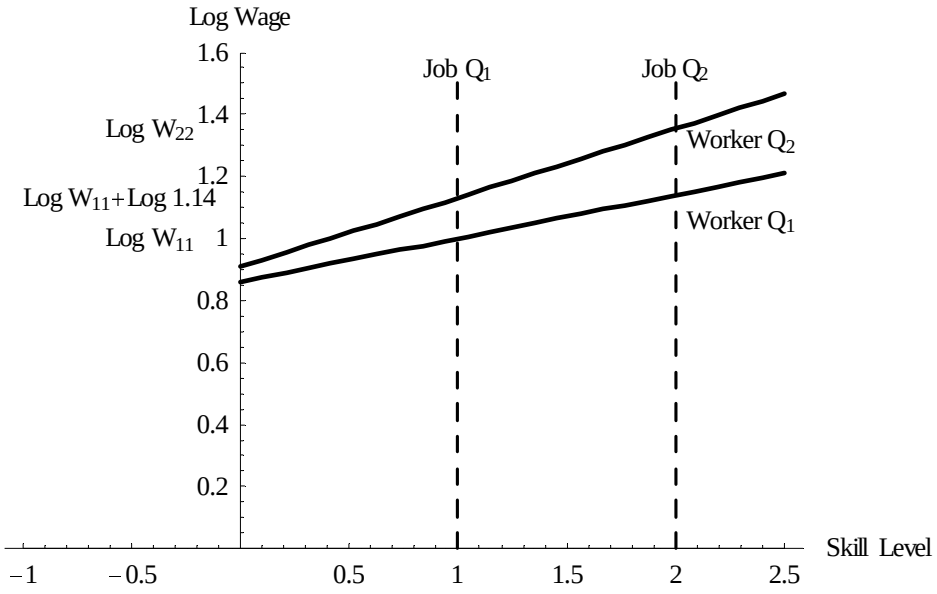

Figure 5: Wages versus Skill Levels in OECD and Quintini Results

of overskilling on wages are much smaller. The wage effects of qualification mismatches are substantially reduced using a fixed-effects regression model to reduce consequences of individual heterogeneity.

In an attempt to represent the results in a single graph, Figure 5 combines the results in Tables 4 and 5 under the simplification that there are two types of workers and two types of jobs.

Leuven and Oosterbeek also relate overeducation and undereducation to theories of job competition, signaling/screening, preferences, and search and frictions. They conclude that the results of the overeducation literature do not provide a guide to investment in schooling because the estimated wage equation cannot be interpreted as a causal relation. However, they regard the results of such equations as potentially informative about the costs of mismatch and they encourage continuing work on efficiency questions arising from overeducation.

Skills Mismatches versus Educational Mismatches Consistent with heterogeneity in jobs and workers, mismatches occur in skill categories as well as in educational level. Jim Allen and Rolf van der Velden (2001) consider the relation between skill mismatches and educational mismatches and their relative contributions to wages, job satisfaction, and job mobility. Using Dutch data from a project providing data on eleven European countries and Japan, Allen and van der Velden base the measures of educational and skill mismatches on self-ratings. For educational mismatches, data include measures of both level

and field. Skill mismatches are based on whether respondents agree with the following statements:

1. My current job offers me sufficient scope to use my knowledge and skills.

2. I would perform better in my current job if I possessed additional knowledge and skills.

Disagreement with the first statement indicates skill underutilization, while agreement with the second statement indicates a skill deficit. Allen and van der Velden find that about 15 percent of individuals indicate skill underutilization, and about 49 percent indicate skill deficit. The two categories are not mutually exclusive, since the responses to the two questions are only weakly related and about 6 percent indicate skill underutilization simultaneously with skill deficits. The authors find that educational mismatches are only weakly related to skill mismatches, contrary to what they expected based on a hierarchical assignment model. However, assignment theory does not assume or require that skills and educational levels will be highly correlated. Using data from the Household, Income and Labour Dynamics in Australia (HILDA) database, Kostas Mavromaras, Seamus McGuinness and Mark Wooden (2007) similarly find low correlation between overeducation and overskilling. In estimates of wages, Allen and van der Velden find that skill underutilization has a significant negative effect, skill deficits have negligible effects, and skill mismatches in general have small effects relative to educational mismatches.

The recent OECD Employment Outlook (2011b) supports the conclusion that qualification and skills mismatches are weakly related. Using responses on the European Survey of Working Conditions for nineteen European countries plus Estonia, Norway, Slovenia, Switzerland and Turkey in 2005, the percentage overqualified is 25.3 percent and the percentage underqualified is 22.2 percent. The percentages of workers in each qualification and skill category are as follows:

Table 6: Percentages of All Workers by Skill and Qualification Mismatch Status

	Overqualified	Underqualified	Matched	Totals
Overskilled	8.4	6.5	17.8	32.7
Underskilled	3.3	2.6	7.3	13.2
Matched	11.4	12.3	30.7	54.4
Totals	23.1	21.4	55.8	100

Source: OECD, 2011b, p. 201. Note: Totals do not add up because of rounding.

This table exhibits basic patterns of mismatches:

- In a labor market, some workers are overqualified at the same time that other workers are underqualified. The presence of overqualified workers does not mean that the labor force is receiving too much education, and the presence of underqualified workers does not mean that the labor force is receiving too little education.
- Similarly, some workers are overskilled at the same time that other workers are underskilled.
- Being well matched with respect to qualifications does not rule out

workers being mismatched with respect to skills. Specifically, 44.9 percent of workers who are well matched with respect to qualifications (calculated as (17.6+7.3)/(17.6+7.3+55.1)) are mismatched with respect to skills. Similarly, 43.6 percent of workers who are well matched with respect to skills are mismatched with respect to qualifications.

- Only a minority of workers (30.7 percent) are well matched with respect to both qualifications and skills, and the majority of workers (69.3 percent) are mismatched either with respect to qualifications or to skills.
- Overqualification does not imply the same relative mismatch with respect to skills. Specifically, 14.3 percent (3.3/23.1) of overqualified workers are underskilled. Similarly, 19.9 percent of overskilled workers are underqualified.
- In general, mismatch with respect to qualifications is only weakly related to mismatch with respect to skills. The percentage of overqualified workers who are overskilled (36.4 percent) is only slightly higher than the percentage of underqualified workers who are overskilled (30.5 percent). Although there is some positive relation between being overqualified and being overskilled, the relation is not very strong.

Etienne Wasmer, Peter Fredriksson, Anna Lamo, Julián Messina and Giovanni Peri (2007), in an analysis of the macroeconomics of education, consider skill mismatch and over-qualification in Europe. They consider whether skill mismatch is a temporary condition for individual workers or a long-lasting episodic phenomenon arising from rapid changes on either the demand or supply side. Mismatches are determined from two questions in the European Community Household Panel (ECHP):

1. Do you feel that you have skills or qualifications to do a more demanding job than the one you have now?
2. Have you had formal training or education that has given you skills needed for your present type of work?

The first question determines whether the individual is overqualified, and the second question determines whether the individual is mismatched. The answers generate four categories labeled as follows:

- NOWM ("non-over-qualified and well-matched"): the individual is not over-qualified (a negative answer to the first question) and education and training are suited for the job (a positive answer to the second question)
- NOBM ("non-over-qualified and mismatched")
- OWM ("over-qualified but correctly matched")
- OBM ("over-qualified and mismatched")

Data are combined for countries and years available, but limited to full-time employees 15 to 64. About 54 percent indicate that they are over-qualified (yes to the first question), and about 42 percent indicate that they are mismatched (no to the second question) (2007, Table 5.1). Only about 21 percent are in the category NOWM. The percentage with NOWM increases with age, and the percentage with over-qualification decreases with age. NOBM and OWM do not appear to change with job tenure, while OBM declines. Using weighted averages for ten European countries, there is a stable incidence of skill mismatch, with a slight decline in OWM combined with an increase in properly matched

individuals, contrary to what one would expect from a deepening long-run aggregate mismatch. The data support the argument that employment protection legislation makes it more difficult for younger workers to find a job without a skill mismatch.

Wasmer et al also undertake an analysis to examine the relation between personal characteristics and the mismatch categories. Male workers are more likely to be over-qualified. Over-qualification also increases with years of education (except that the relation is not significant for Germany). Over-qualification declines with labor market experience in all countries. The authors also apply multinomial logit to analyze all four categories. Estimates of wage equations incorporating over-qualification and mismatch variables suggest that wage penalties are generated by skill mismatches rather than over-qualification.

Jim Allen and Egbert de Weert (2007) examine the relation between educational and skill mismatches further using comparable survey data for graduates from Spain, Germany, the Netherlands, the United Kingdom, and Japan. Educational and skill mismatches are generally related: graduates in jobs above their educational level or outside their fields use less of the skills and knowledge from university than those in matching jobs. The relation between educational mismatches and use of skills and knowledge is weakest in Germany and the Netherlands, and greatest in the United Kingdom and Japan.

Francis Green and Steven McIntosh (2007) use results from the 2001 British Skills Survey to examine the relation between qualification mismatches (in terms of education) and use of skills. They find that that there is a positive relation between overqualification and overskilling. However, since the correlation between the two conditions is low (0.20), less than half of workers who were overqualified were also overskilled. The results support their view that one of the explanations for observed qualification mismatch is that many workers with the same qualifications have heterogeneous skill levels, so that some overqualified individuals may in fact have appropriate skills for their jobs.

Underqualification and overqualification may compensate for other costs of employment. Joni Hersch (1995) argues that overqualified workers need less training, and underqualified workers are less likely to quit the firm. As a result, firms are willing to hire overqualified or underqualified workers, and the resulting assignment can be optimal.

Vertical versus Horizontal Mismatches Horizontal mismatches arise when a worker's field of preparation differs from the field of the worker's job. When workers find jobs outside their field of preparation, they must often accept jobs that have lower educational or qualification requirements than they possess. Using 2004 data from the European Social Survey for 22 OECD countries, 31 percent of workers have jobs in areas unrelated to their preparation fields (OECD, 2011b, p. 204; see also Quintini, 2011a, Annex 4.A4). For overqualified workers, the percentage is higher, 40 percent. Robst (2008) analyses 1993 data on U.S. graduates and finds that vertical mismatch is more common than horizontal mismatch. Robst finds that horizontal mismatch has a negative effect

on wages. Whereas overeducated workers suffer a wage penalty of 7 percent, the wage penalty triples for overeducated workers who are also working in a job unrelated to their field of graduation.[4]

2.2.2 Business Cycle Mismatches

The state of the economy can have significant effects on levels of mismatches. Periods of high unemployment, such as the recession following the 2008 crisis, make it difficult for unemployed workers to find jobs that match their qualifications. New entrants, particularly graduates with higher levels of education, find it difficult to establish themselves in the labor market and often take jobs for which they are overqualified. During business cycle peaks, employers find it difficult to hire qualified workers and often must settle for underqualified workers that must be trained. As a result, mismatches can be expected to change systematically over the business cycle.

The business cycle directly affects the likelihood of mismatches for individual workers. Getting fired or losing a job at a firm that is closing significantly increases the likelihood that a worker will be overqualified or overskilled in the next job, compared to a voluntary separation (OECD, 2011b, p. 208). Time spent between jobs increases the likelihood of overqualification.

Truman Bewley's interviews with firms (1999) show how firm hiring conditions vary with the business cycle. During a recession, 68 percent of businesses experienced an improvement in the quality of applicants (Bewley, 1999, p. 278), making it more likely that they would hire workers with greater qualifications. About 88 percent of businesses observed that some applicants were overqualified, and 80 percent of businesses were totally or partially unwilling to hire them (Bewley, 1999, pp. 382-383). Major reasons that businesses shunned hiring overqualified applicants included concern that they would quit for better jobs as soon as possible (78 percent), they would be unhappy with the job (50 percent), or their skills would be rusty (10 percent). In spite of the recession, 16 percent continued to experience shortages of particular skills. These results indicate that during a recession, the pool of unemployed consists of workers who are more qualified for the jobs available, and those who are overqualified face substantial difficulty in finding employment near their levels of qualification.

Hiring overeducated workers during a recession may be part of firm recruitment strategies to ensure that the firm will continue to have high skills available to it during a recovery (CEDEFOP, 2012, p. 7). Firm level data indicates that overskilling contributes to firm productivity (CEDEFOP, 2012, p. 6), justifying an employment strategy of hiring overqualified workers.

The business cycle may affect sectors of the economy unequally, generating different ratios of unemployed workers to vacancies in labor submarkets. Search behavior by workers and firms then produces unequal unemployment rates. Measures of mismatch can be based on the differences between ratios

[4] Calculations of horizontal mismatches using European data sources are provided by E. Berkhout, S. Van der Werff and A. Heyma, 2010, and J. Koucky, C. Meng & R. Van der Velden, 2007.

of vacancies to unemployed, even though they do not explicitly describe the heterogeneous characteristics of workers and jobs. From the comments by Diamond and Kocherlakota in the introduction, measures of mismatches have been used by economists studying aggregate labor markets to explain shifts in the Beveridge curve relating aggregate unemployment to aggregate vacancies in an economy.

Richard Layard, Stephen Nickell and Richard Jackman (1991, Chapter 6) provide an index of mismatches based on differences in unemployment rates among disaggregated labor markets. The measure indicates the proportional increase in unemployment over the minimum that would occur if all unemployment rates were equal. Jackman and Roper (1987) develop measures of mismatches (or structural imbalances) based on differences within sectors between the proportion of aggregate unemployed in the sector and the proportion of aggregate vacancies in the sector (equivalently, the ratio of vacancies to unemployed varies among sectors). In their analysis, mismatches (or structural imbalances) arise when the characteristics of unemployed workers (in terms of skills, experience or location) differ from the corresponding characteristics of jobs in the same sectors. Compared to a labor market with equal proportions across sectors, the consequence of unequal proportions of aggregate unemployed and vacancies is that the hiring rate is below the rate that would otherwise occur, and the combination of unemployed and vacancies lies above the relation that would otherwise occur. Jackman and Roper observe a sharp increase in mismatches around 1979-1981 using industrial sectors, primarily caused by imbalances between manufacturing and services (1987, p. 32). Ayşegűl Şahin, Joseph Song, Giorgio Topa and Giovanni L. Violante (2011) develop a related measure of mismatch based on a comparison between the observed pattern of unemployment and the optimal allocation that a planner would choose to minimize the overall unemployment rate. Their measures indicate that less than one percent of the increase in the unemployment rate in the recent recession (starting in 2008 in the U.S.) is attributable to increasing mismatch.[5]

2.3 Methods of Analysis

An important outcome of the extensive literature on wage consequences of mismatches is that the causal interpretation of the empirical results is lacking. Why do rewards and penalties from mismatches arise? Are the rewards and penalties an accurate guide to the improvements that could be obtained with practices that improve matching? Simple versions of human capital theory disregard job characteristics and do not by itself provide an explanation for mismatch wage consequences. Job competition as developed by Lester Thurow (1975) disregards worker characteristics by assuming that workers learn job relevant skills on the job. Many authors have cited assignment theory as superior to these approaches, but assignment theory needs to be extended to explain specific wage

[5] Related work relating mismatches to shifts in the Beveridge Curve include Karsten Albaek and Henrik Hansen, 2004; Gadi Barlevy; 2011; S. Nickell, L. Nunziata, W. Ochel and Glenda Quintini, 2002; and Carsten Ochsen, 2009.

outcomes when worker search and employer recruitment determine how workers end up in jobs. This section first presents the theoretical background for qualitative mismatches based on assignment and search models. Then it considers specific explanations for the wage consequences of mismatches. Finally, the section discusses search and matching models and the limited form of mismatches that they generate.

2.3.1 Theoretical Background

Assignment Models Given the extent of differences among jobs, and corresponding differences among workers, there exists an allocation problem within any economy of deciding which workers will perform which jobs. Using the job characteristics in the previous section, consider the entire economy as one huge firm, and suppose there is a single manager that knows everything. There is a group of workers differing by which job levels in Table 2 they can perform, and there is a group of jobs at one point in time that differ by the characteristics in that table. The problem for the manager is to determine how to assign different jobs to different workers so as to maximize production. The problem of determining which workers should do which jobs is called the assignment problem in the literature, and arises in any type of economy whether or not there is an all-knowing central manager.

Assignment models originate with Jan Tinbergen's analysis of the determinants of income distribution (1951). In this early model, there is a distribution of jobs (varying by some characteristic) and a different distribution of workers. Workers are affected by the mismatch between jobs and their own characteristics. Differences in wage rates arise that reconcile the distributions of jobs and workers by compensating workers for taking a job that does not match their characteristics. Tinbergen later implemented the assignment model empirically by estimating trade-offs between different types of labor and using the estimates to analyze changes in the relative wages of college (university) graduates (1975). Based on the empirical model he developed, Tinbergen characterized the evolution of wage differences as a race between technology and education. He documented the substantial decline in wage differences (between incomes for workers with college training and average incomes) from 1900 to the time of publication of the book in 1975, but foresaw the possibility that, at least in the United States, the race could be lost by education (1975, p. 103).

Alternative forms of the assignment model have been developed following Tinbergen's original contribution. A.D. Roy (1951) considers how individuals would choose between sectors. Robert Willis and Sherwin Rosen (1979) adapt the Roy model to consider how individuals choose among educational levels, and James Heckman and Guilherme Sedlacek (1985) and Heckman and Bo Honoré (1990) estimate empirical versions of the Roy model. Tjalling Koopmans and Martin Beckmann (1957) apply the operations research assignment model to explain how activities would be assigned to different locations in a way that is directly analogous to a labor market. Sattinger (1975) explains how comparative advantage operates in an assignment model (see also the survey in Sattinger,

1993). Comparative advantage operates in a labor market in a manner similar to its operation in international trade. In David Ricardo's theory, a country produces one good (cloth) rather than another (wine) when producing extra cloth and trading it for wine yields more wine for the country than it could get by producing the wine itself. Comparative advantage works in the same way in a labor market. Using Adam Smith's example of the pin factory, suppose Ernest draws out wires for pins and Maikel cuts them. Suppose the numbers they can perform in an hour are given in the following table.

Table 7: Performances of Ernest and Maikel at Pin Factory

	Drawing out wire for pin	Cutting wire for pin
Ernest	90 per hour	120 per hour
Maikel	60 per hour	90 per hour

Ernest can get his job done in two ways. He can draw out wires himself, or he can ask Maikel to draw out wires while he does Maikel's job. Can Ernest save any time by switching jobs? In an hour, Ernest can cut wires for 120 pins. In the time it takes Maikel to cut 120 wires, he could draw out wires for 80 pins.[6] That is not enough. Ernest would end up with 10 fewer wires drawn out than if he did it himself, and he would need to spend extra time making up the difference. A manager that knows what each worker could do would assign Ernest to draw out wires and Maikel to cut them. As in international trade, we would say that Ernest has a comparative advantage at drawing out wires and Maikel has a comparative advantage at cutting them. When comparative advantage occurs in a labor market, it determines how workers should be assigned to jobs.

Coen Teulings (1995) adapts assignment models to compare wage differentials in two economies, or in a single economy at two points in time. Comparing an economy at two points in time, if a given type of worker is assigned to a more complex job at the later point in time, the wage differential will be steeper. Teulings applies data for the Netherlands to show that between 1982 and 1988, worker skills increased more rapidly than job complexity. Then in the 1988 assignment of workers to jobs, each type of worker was in a less complex job and wage differentials were lower, explaining a reduction in inequality. Teulings' model offers an alternative basis for Tinbergen's race between education and technology.

Arnaud Costinot and Jonathan Vogel (2010; see also Costinot, 2009) extend the theory of comparative advantage to large numbers of goods and factors in a model that is relevant to both international trade and the assignment of workers to jobs. They develop a Roy assignment model with a continuum of workers that are matched to a continuum of tasks or intermediate goods, and the tasks or intermediate goods are then aggregated into a final good using a continuous CES function. Their development makes it possible to derive monotone comparative statics predictions that are relevant to changes over time (see Wing Suen, 2007, for comparable results in a differential rents assignment model). They use the

[6] Note that Ernest gives up drawing $\frac{3}{4}$ of a wire for every wire cut, while Maikel gives up drawing 2/3 of a wire for every wire cut. So in an economic sense Ernest has a higher cost of cutting wires.

results to examine consequences of globalization including technological change and offshoring. These results are particularly relevant to long run qualitative mismatches.[7]

Job Search With free and perfect information about each worker, finding the worker for a particular job would be no more difficult than finding a book in a library, and the labor market would be reduced to a Dewey Decimal system. However, along with the great heterogeneity in jobs and workers, the labor market is also characterized by costly and incomplete information about workers and jobs.

Consider an unemployed individual looking for a job. The individual checks with friends and relatives about jobs, reads help wanted ads, looks online, and submits job applications to different firms. The individual may not know whether a particular firm is seeking to hire someone, or whether the job's requirements match the individual's qualifications. When the individual submits an application to a firm, the firm may make an offer depending on how similar the worker's qualifications are to the job requirements. Then the worker needs to decide whether to accept that job offer or continue searching. On the one hand continuing to search could lead to a better match between the worker's qualifications and the characteristics of the job, with a correspondingly higher wage rate. On the other hand, continuing to search means the individual remains unemployed for a period of time and does not receive employment income. Search theory describes an individual's problem in deciding when to accept a job offer. Unemployment benefits, costs of looking for a job, and the current unemployment rate (by influencing how long it will take the individual to find a job) all affect the wage rate than an unemployed worker would be willing to accept. Search theory explains how unemployment and wage differences are generated for workers.[8] Although the original search theory explained many features of the labor market, such as why unemployment occurs, it did not explain the source of differences in wage offers, a shortcoming noted by Diamond (1971). General equilibrium search models and search and matching models explain both sides of the labor market.

The significance of the problem of searching for jobs and workers is that it prevents the labor market from generating the best (optimal) assignment. With costly search, a worker would typically accept a job before finding the optimal job, and an employer would typically accept a worker before finding the optimal worker. As a consequence, the optimal assignment of workers to jobs could not be achieved. With search, the combination of worker qualifications and job characteristics at a particular job would differ from the optimal combination, and

[7] Recent work on assignment models includes Teulings, 2005; R. M. Costrell and G.C. Loury, 2004; X. Gabaix and A. Landier, 2008; L. Garicano and E. Rossi-Hansberg, 2004; and M. Tervio, 2008.

[8] See the Nobel Memorial Prize lectures by Peter Diamond, 2011, Dale T. Mortensen, 2011, and Christopher A. Pissarides, 2011, as well as surveys by Mortensen and Pissarides, 1999; Richard Rogerson and Robert Shimer; 2011; and James Albrecht, 2011. Firms also engage in search for workers (Paul Oyer and Scott Schaefer, 2010).

this difference would constitute a qualitative mismatch. Short run qualitative mismatches would arise even if aggregate worker characteristics corresponded to aggregate job characteristics.

Assignment with Search Search by workers and firms can be regarded as a labor market mechanism that assigns workers to jobs less accurately than in an economy without the frictions requiring search. Assignment and search together provide the theoretical explanation for how mismatches arise. With an underlying assignment problem, search by workers and employers generates not only unemployment and vacancies but also mismatches between workers and their jobs. The model developed by Sattinger (1995) shows how wages can vary depending on overqualification or underqualification. Similar wage differences can be generated in an assignment model with overlapping labor markets (Sattinger, 2006).[9]

Teulings and Peter Gautier (2004) combine assignment and search in a model that examines the costs of search, including mismatches.[10] In the underlying assignment problem, workers with greater skill have a comparative advantage at more complex jobs. Output produced by different workers is not perfectly substitutable, generating a trade-off among different workers that changes with the difference between their types. That is, workers that are more similar can be substituted more easily for each other, in a structure previously developed by Teulings (1995). Teulings and Gautier first consider the optimal assignment and then introduce search frictions. With search frictions, workers accept a wider range of jobs than they would with the optimal assignment, and similarly for employers. The cost of search is measured by the relative difference between a worker's value added in the optimal job and the lowest amount the worker would accept in a job. This cost of search is greater when workers are less easily substitutable for each other. Teulings and Gautier are able to break down the costs of search into three components: unemployment, vacancies and mismatches. If the bargaining power between workers and employers is equal, these three components are equal. This suggests that the costs of mismatches to the economy are equal in magnitude to the costs of unemployment.

In a hierarchical model with search (in which more skilled workers would optimally be assigned to jobs that are more productive), the pattern of assignment of workers to jobs differs from the pattern that would arise in an optimal allocation, generating mismatches. These hierarchical mismatches correspond to vertical mismatches. Gautier and Teulings (2011) analyze output losses from

[9] Connections between mismatches and the underlying assignment problem are discussed in Lex Borghans and Andries de Grip, 2000; Jacques-François Thisse and Yves Zenou, 2000; Hartog, 2000; Allen and van der Velden, 2001; Séamus McGuinness, 2006; Kostas Mavromaras and Séamus McGuinness, 2007; Allen and de Weert, 2007; Francis Green and Steven McIntosh, 2007; Peter J. Sloane, 2003; François Rycx, 2010; CEDEFOP, 2010b, p. 29; Quintini, 2011b, p. 10; and Catherine Béduwé and Jean-François Giret, 2011.

[10] Other labor market analysis that combines assignment and search includes Ramon Marimon and Fabrizio Zilibotti, 1999; Robert Shimer and Lones Smith, 2000; Giuseppe Moscarini, 2001; Shimer, 2007; Juan Dolado, Marcel Jansen and Juan Jimeno, 2009; and Jan Eeckhout and Philipp Kircher, 2011b.

search frictions using a circular model, corresponding to horizontal mismatches. In a circular model, workers and jobs have characteristics that are placed around a circle. These characteristics correspond to different types of workers and jobs rather than having more or less skill or complexity. For a worker, having a job further away along the circle would generate a less favorable match. Because of costly search, workers generally find jobs close to their placement on the circle, but not exactly at the same place. Gautier and Teulings find that the mismatches generated by search frictions cause a loss of output between 7 and 15.6 percent (see also Gerard van den Berg and Aico van Vuuren, 2010, for estimates of effects of search frictions on wages and labor productivity). The output loss depends on the wage determination mechanism (Pieter Gautier, Coen Teulings, and Aico Van Vuuren, 2010).

2.3.2 Causes of Wage Rewards and Penalties

This section describes economic reasons why the wage consequences of qualitative mismatches may arise. The list is not exhaustive. For example, Irene Valsecchi (2000) considers effects of imperfect information on job assignment and promotion. Wage consequences depend on whether worker characteristics are privately or publicly known.

Production The simplest explanation for wage consequences of qualitative mismatches is production. The wage in a qualitative mismatch would be determined by the value of the marginal product of a worker in that job, as determined by characteristics of the worker and job.[11] The productivity and marginal productivity of a worker at a job could be determined from a production function that depends on both worker and job characteristics. Simple versions of the Human Capital Model, in which the wage is determined only by the worker's human capital, could be included under this heading. This explanation disregards the reasons why qualitative mismatches occur and the costs to workers and firms of finding matches. While production would seem to provide a straightforward explanation for wage consequences of mismatches, a wage based on marginal productivity would leave surpluses or deficits for employers, with no explanation for how they would be apportioned to workers or their employers.

Preferences Preferences as an explanation for wage consequences arise in Tinbergen's early assignment models but can be extended to other non-wage consequences of assignments. In Tinbergen's 1951 and 1956 models, workers prefer employment at jobs for which the requirements match their capabilities. Since the distributions of worker capabilities and job requirements differ, wage differences arise that direct them to choose the jobs they would get in equilibrium. Introducing search frictions and some randomness in assignment into

[11] François Rycx (2010), considered in the next subsection, provides direct evidence of effects of mismatches on firm productivity.

such a model, wages in different jobs would be partly determined by the disutility experienced by workers from the difference between their capabilities and the job requirements. An overqualified worker would need to be compensated with a higher wage compared to an equally qualified worker at a well-matched job. Similarly, an underqualified worker would also need to be paid more than a worker with the same qualifications who was well matched. These wage comparisons do not correspond to the results in Tables 4 and 5, where an overqualified worker is paid less than an equally qualified worker at a well-matched job.

However, as an alternative version, the literature describes differences in job satisfaction and career prospects that arise as a consequence of qualitative mismatches. It seems likely that these non-wage job aspects would generate compensating wage differentials in mismatches. A higher wage for an underqualified worker (compared to a worker with the same qualifications in a well-matched job) would then compensate for worse non-wage characteristics of being in the job, perhaps lower levels of job satisfaction unrelated to the wage. Similarly, a lower wage for an overqualified worker would be explained by better non-wage characteristics of being in the job.

Nash bargaining with random matching Although assignment models suggest the determinants of wages in qualitative mismatches, the early frictionless models of assignment do not generate mismatches. Assignment models need to be combined with some mechanism generating mismatches (e.g. search) and a mechanism determining wages when mismatches occur. Sattinger's model of assignment with search (1995) combines assignment with Nash bargaining for wages from random meetings between workers and jobs, and generates wage consequences for mismatches. The consequences of Nash bargaining for wages in qualitative mismatches can be seen most simply in a model with two sectors in which workers randomly search and find jobs in one of the sectors and then engage in Nash bargaining for the wages. There are no differences in likelihood of finding a job in one sector or another, and no differences in unemployment. Without comparative advantage, this simple model generates the following wage differences:[12]

Table 8: Wages Generated by Nash Bargaining

	Job Type 1	Job Type 2
Worker Type 1	0.5	0.506
Worker Type 2	0.794	0.845

As in the empirical literature, underqualified workers earn more than their well-matched individuals with the same qualifications, while overqualified workers earn less. Furthermore, the wage penalty for overqualified workers is substantially greater than the wage reward for being underqualified. The wage

[12] Output a_{ij} from a match between worker i and job j is given by $a_{11} = 1$, $a_{12} = a_{21} = 1.3$, and $a_{22} = 1.69$, the numbers of workers and jobs of each type are 1, the break-up rate of workers and jobs is .05, the matching function is given by $uv/(u+v)$, where u is number of unemployed and v is number of vacancies, and the bargaining power between workers and employers is equally divided ($\beta = .5$).

consequences for underqualified workers can be seen from the equations determining their wages:

$$w_{11} = w_{01} + \beta(a_{11} - w_{01} - z_{01}) \quad (1)$$
$$w_{12} = w_{01} + \beta(a_{12} - w_{01} - z_{02}) \quad (2)$$

In the above, w_{ij} is the wage of worker i in sector j, a_{ij} is the output from worker i in sector j, w_{0i} is the reservation wage of a worker of type i, and z_{0j} is the reservation profit of an employer in sector j. The wage reward for the underqualified worker is given by $\beta(a_{12}-a_{11}-(z_{02}-z_{01}))$. Since the reservation profit increases by less than output in moving from sector 1 to sector 2, workers earn more in jobs where they are underqualified, compared to what they would earn in a well-matched job.

Nash bargaining also predicts the relative size of rewards and penalties from mismatches. The penalty from being overqualified $(w_{22} - w_{21})$ minus the reward from being underqualified $(w_{12}-w_{11})$ is given by $(a_{22}-a_{21})-(a_{12}-a_{11})$. If the difference in outputs between two types of workers increases at more productive jobs, then the penalty from overqualification will be greater than the reward for underqualification.

Employer strategies in attracting applicants An important consideration of employers is attracting qualified applicants (Searle, 2005, p. 5). Employer strategies in attracting qualified workers play an important role in Shimer's assignment model of coordination frictions (2005) and generate wage consequences for overqualified and underqualified workers that were not analyzed in the original model. In Shimer's model, there are different types of workers and different types of jobs, with output being greater for higher levels of jobs and higher levels of workers. Employers follow an optimal strategy of hiring the most qualified worker but lose production and profits from a vacancy if no one applies for their job. Workers choose where to look for a job and face the problem that if they apply for a higher type of job, they are less likely to get it because they would lose the job to a higher type of worker. The coordination frictions in the title of the paper arise because if more than one worker applies for a job, only one worker will get a job, and if an employer gets no applications, no production will take place. The wage rate is determined by the marginal product of a worker, given by what the worker produces minus the expected production if the worker had not applied to the job. As a consequence, a less qualified worker is more valuable as an applicant because (assuming the less qualified worker would have gotten the job) the employer would have been more likely to suffer a vacancy without that worker's application. This generates the result that an underqualified worker at a job receives a higher wage than a well-matched worker at that job would have received. While the equilibrium and wages in this model are in general difficult to work out, the model simplifies substantially when reduced to two sectors. With equal numbers of types of workers and types of jobs, and the same outputs from worker and job combinations as in the Nash

bargaining example worked out in the previous section, the wages are:[13]

Table 9: Wages in Shimer Coordination Friction Model

	Job Type 1	Job Type 2
Worker Type 1	0.622	1.226
Worker Type 2	0.675	0.959

As shown, the Shimer model generates the unusual result that underqualified workers are paid more than more qualified workers in the same job (1.2264 versus 0.9586), and the penalty for underqualification (.9586 - .6754) is less than the reward for overqualification. However, an important feature of the Shimer model is that workers face different likelihoods of finding a job at the two types of employers, as shown in the following table:

Table 10: Likelihood of Finding Job in Shimer Coordination Friction Model

	Job Type 1	Job Type 2
Worker Type 1	0.596	0.345
Worker Type 2	0.948	0.661

The table shows that the higher wage for a worker type 1 at a job type 2 compensates for the reduced likelihood of getting a job, and the greater likelihood of a worker type 2 in finding a job type 1 compensates for the lower wage. The results also show that the incidence of overqualification is 7.3 percent, while the incidence of underqualification is 3.5 percent.

The Shimer model perhaps yields extreme results (particularly in that underqualified workers get paid more than their well-matched workers in the same job) because it is not dynamic. Workers search simultaneously and do not get a second chance to find a job. As a result, unemployment and vacancies are very costly and the compensating differentials for differences in finding or filling a job are large. In a model with multiple periods or continuous time, workers would only be delayed in not finding a job, and the coordination problem of workers simultaneously applying for the same job would be reduced.

Training as an alternative to hiring matched workers Melvin Reder, in a paper on occupational wage differentials (1955), describes the alternatives for a firm facing a market for skilled labor in short supply. The firm can pay the going wage, lower its hiring standards, or hire less skilled workers and train them. Hiring standards are relevant to long run qualitative mismatches and will be discussed then. In this section, the cost of training workers will be regarded as placing a limitation on the wage differentials that can arise between skill levels. If the wage differentials are too large, firms hire less skilled workers instead and train them for the positions. This view regards wage determination and decisions to offer training as being determined simultaneously. In contrast, the literature on qualitative mismatches often regards instances of underqualification as occurring randomly, followed by firms offering training in an attempt to reduce the consequences of the mismatch.

[13] The solution strategy is to solve first for the search strategies of workers, i.e., the mixed strategy given by the likelihood of seeking a job at each type of firm, by maximizing aggregate output. Then other elements of the equilibrium can be directly calculated.

Reder's view, combined with Gary Becker's analysis of on-the-job training, explains why workers would gain a reward for taking jobs where they are underqualified. Suppose a firm chooses to hire a worker who is underqualified for the job and then provide the worker with the skills needed to perform the job (so that the worker is well-matched after receiving the training). There will be an advantage to the firm in hiring the worker in savings from paying a wage lower than a matched worker would receive at the job. However, the firm runs the risk of the worker quitting before working an adequate time as a well-matched employee. The worker and firm will instead split the surplus from the training, providing both with incentives to maintain the long-term relationship as described by Becker. The division of the surplus will depend on extent of specific versus general content of the training and mobility in labor markets. As a consequence, a worker receiving training that provides the skills required for the job would be paid more than a worker with the same initial set of qualifications who is well-matched.

More generally, wage determination in qualitative mismatches should not be treated as occurring in auction markets and instead should be viewed as part of firm strategies for recruiting, training and retaining workers over their careers.

Summary The discussion in this section does not propose a single model as an explanation for the wage consequences extensively observed in the literature. Among the models, the Nash bargaining approach provides results that are closest to what is observed. All of the approaches suggest factors that could influence wages in mismatches. Clearly more empirical work is needed to distinguish among competing explanations before the ambiguity in interpreting wage regression results can be resolved.

2.3.3 Search and Matching

The search and matching literature has had remarkable success in providing a coherent general equilibrium model of an economy with a labor market, culminating in the Nobel Memorial Prizes for Peter Diamond, Dale Mortensen and Christopher Pissarides. Matching arises from Boyan Jovanovic's description (1979) of the hiring process in which the amount of production from a worker at a firm is unrelated to observable characteristics of the firm or worker and must be discovered over time. The outcome of the job search process is described abstractly by a matching function that relates the number of matches formed between workers and employers to the numbers of unemployed workers and vacant positions. Although the terms assignment and matching are often used interchangeably, matching can be characterized as abstracting from the qualitative differences among workers and among jobs that are essential elements in assignment theory. In Jovanovic's analysis, the outcome of a worker-job match provides no information on characteristics of the worker or job that would be relevant to future matches for the worker or the job. In Pissarides (2000, p. 22), the rate of matching between unemployed workers and vacant jobs depends on the extent of mismatches generated by the search and meeting process. Under

the assumption that the rate at which mismatches are generated is stable over time, the matching function abstracts from the qualitative features of workers and jobs that generate mismatches. As a result of this assumption, the matching function does not make explicit reference to characteristics of workers or requirements of jobs.

In the absence of qualitative characteristics of workers and jobs, coordination frictions provide a basis for generating a matching function (see the discussion in Barbara Petrongolo and Pissarides, 2001, pp.401-402). In this process, each of U unemployed workers sends an application to one of V vacancies. Since the workers are uncoordinated, some of the vacancies get no applications, and some of the vacancies get more than one application. When a vacancy gets more than one application, only one is chosen, leaving the rest of the workers unemployed. Mismatches in this context are unrelated to characteristics of workers and jobs and instead take the form of lost output from unemployment and vacancies. When U and V are large, this process leads to a specific functional form for the matching function.

A general matching function is used in search and matching models (Pissarides, 2000; Mortensen and Pissarides, 1999) to describe the aggregate characteristics of a labor market, including the Beveridge Curve relating vacancies to unemployment, the job finding rate, and the unemployment rate. Shimer (2007) provides an alternative to the search and matching model that does not depend on a matching function, and instead is based on aggregation of unemployed and vacancies generated by mismatches over separate labor markets. Mortensen (2008) develops a related model in which workers and firms seek matches in labor markets located on separate islands, with aggregation generating a matching function.

Kenneth Burdett and Dale Mortensen (1978) develop a general equilibrium model of a labor market in which worker on-the-job search generates heterogeneous search behavior by workers, thereby providing firms with an incentive to offer different wage rates. Workers may be unemployed or employed. If they are employed, they continue to search for a job that pays more than their current job. The model generates an equilibrium distribution of wage offers by firms such that firm profits are the same at each wage rate. The model explains how identical workers could be paid different wages (Mortensen, 2003). It can be extended to incorporate differences in productivities of firms, and can be used for empirical analysis (see the review of worker and firm heterogeneity in Rasmus Lentz and Mortensen, 2010). With heterogeneous productivities among firms, mismatches arise because a worker's current productivity in a job is low relative to what could be produced in an alternative match. Reallocation of workers from less productive employment to more productive employment then raises aggregate productivity (Lentz and Mortensen, 2005).

Search and matching models that do not incorporate explicit heterogeneity in workers and jobs are useful in explaining aggregate labor market behavior, including dynamics in response to shocks. Although their construction is based indirectly on the presence of potential mismatches, they are limited in describing current or future mismatches in terms of skills, education, or other

characteristics of interest. While the search and matching literature is not useful in explaining wage consequences of qualitative mismatches related to worker and job characteristics, the qualitative mismatch literature could be relevant to search and matching models of the aggregate labor market.

As noted by Pissarides (2000, p. 22-23), an exogenous change in qualitative mismatches would affect the rate of job mismatches at any given combination of unemployed and vacancies, shifting the Beveridge Curve relating unemployment to vacancies. Using education as an example, an increase in educational requirements at jobs relative to supplies of workers at higher educational levels could reduce the rate at which matches are formed for given levels of unemployed and vacancies, generating a shift in the Beveridge Curve. A recession as caused by the 2008 financial crisis would increase unemployment disproportionately among less qualified workers, increasing their representation among the unemployed. This compositional shift in the unemployment pool would affect the likelihood of a randomly chosen unemployed worker finding a job and reduce the job finding rate for given levels of unemployment and vacancies. The methods to observe business cycle mismatches from unequal unemployment conditions in different sectors only consider limited forms of mismatch and do not incorporate consequences of qualitative heterogeneity in workers and jobs. Some steps have been taken to incorporate qualitative mismatches in the search and matching model. A simple extension is to consider a limited number of worker and job types under the assumption that a stable matching function would operate between each worker and job type.

Giuseppe Moscarini (2001) incorporates comparative advantage into the search and matching model. There are two sectors of the economy, and workers have a two-dimensional vector of skills. Workers with different skills choose different strategies in searching for jobs. They balance the wage advantage from searching in the sector where they have comparative advantage with the greater job-finding rate from random searching. As a result, workers divide into three groups: those with a strong comparative advantage at sector 1, who only search in sector 1; those with a strong comparative advantage in sector 2, who only search in sector 2,; and workers with weaker comparative advantage who randomly search in both sectors. As a consequence, a positive proportion of workers take jobs in sectors where they do not maximize their labor market gains, and continue searching while employed at a job where they are mismatched. Changes in the job finding rates from a recession make it more attractive for workers to search randomly, generating greater mismatches and what Moscarini terms as "excess worker reallocation."

James Albrecht and Susan Vroman (2002) introduce endogenous skill requirements into an economy with high and low skill workers and high and low productivity jobs. Only high skill workers can perform high skill jobs, but low skill workers randomly seek jobs at either high or low skill jobs. Some high skill workers end up at low productivity firms, generating mismatches. The free entry condition for firms allows them to choose either a high skill requirement or a low skill requirement, so that the proportion of high skill jobs responds to labor market conditions. High skill workers earn more in high skill jobs than in

low skill jobs.

Albrecht and Vroman consider endogenous skill requirements in a limited way, in the firm choice about whether to open a low skill or a high skill vacancy. In an alternative that allows continuous variation in skill requirements, Sumati Srinivas and Michael Sattinger (2007) consider the firm problem in setting employment criteria when a firm infers whether a worker is high skill or low skill from an imperfect test observation. The employment criterion responds to the relative profits and losses from hiring a high versus a low skill worker as well as the composition of the pool of unemployed, which affects the likelihood of getting a high or low skilled worker.

Dolado, Jansen and Jimeno (2009, p. 222) suggest an extension of search and matching models by incorporating heterogeneity to explain business cycle behavior. In a model with explicit heterogeneity, an aggregate productivity shock would generate variation in the composition of mismatches and level of on-the-job search over the business cycle. This would alter the relation between rate of match formation and the numbers of unemployed workers and vacant jobs.

Javier Birchenall (2011) develops a theory of mismatches in which heterogeneity also takes the form of locations on a circle, as in Gautier and Teulings (2011). Workers are distributed clockwise around the circle starting from an ex ante assignment, and jobs are distributed counterclockwise. Production takes place where workers and jobs overlap on the circle, forming matches, and unemployed workers and vacant jobs occur where there is no overlap. The distance that workers and jobs move around the circle depends on the length (circumference) of the circle, and variations in this length generate short-term variations in unemployment and vacancies. Unemployed workers and vacant jobs are eventually reallocated, so that an increase in unemployment is related to an increase in dispersion across sub-markets on the circle. The model is used to explain the midterm relationship between the unemployment and vacancy rate, which differs from the short-term relationship.

Peter Skott (2012) argues that the presence of overeducation modifies the economy's response to aggregate employment shocks. In a model where efficiency wages affect worker decisions to shirk, an increase in aggregate employment reduces the number of high-skilled workers at low-skill jobs, disproportionately increasing the employment of low skill workers and reducing the relative wage of high skill workers.

In a further contribution to macroeconomic modeling, Jan Eeckhout and Philipp Kircher (2011b; see also 2010, 2011a) consider complementarities and sorting between worker skills and job characteristics, the span of control in organizations, and measurement of complementarities in datasets. Mismatch and the search behavior of workers provide evidence on the extent of complementarities. Considering a given type of worker at different jobs, Eeckhout and Kircher conclude that the match surplus, and therefore the worker's wage, will be an inverted U-shaped function of firm type. That is, as firm type increases, the worker's wage will first rise and then fall.

2.4 Consequences of Short Run Mismatches for Workers and Firms

In a model of the aggregate labor market, Gautier and Teulings (2004) found that losses from mismatches were about equal in magnitude to losses from unemployment, and in a different model (2011) they concluded that losses from mismatches caused a reduction in output between 7 and 15.6 percent. These are substantial amounts and suggest the gains that can be obtained if mismatches can be reduced. This section considers consequences of mismatches for individual workers and firms.

2.4.1 Losses for Workers

Looking at mismatches from the perspective of a worker provides a method of organizing the consequences of mismatches over a worker's career, from human capital investment decisions through obsolescence and retirement. A common observation is that workers upon entering the labor market are willing to take jobs with mismatches in order to gain experience. Many workers in initial mismatches change jobs or get training to compensate for their mismatches, while other workers continue in a condition of mismatched employment. At later ages, changes in jobs may cause worker skills to become obsolete, while technical skills may also decline over time. Along the way they may experience different levels of job satisfaction or wages depending on how well they are matched with their jobs. Specific results for workers over their careers follow.

Type and level of education Decisions of type and level of education can affect workers throughout their careers and increase the difficulty of entry into the labor market. Depending on the field, workers often take jobs outside their field of study, reducing their preparation for work. Workers in horizontal mismatches are also more likely to experience qualification mismatch, interfering with their labor market careers.

Initial entry into the labor market Workers seeking entry into the labor market for the first time are likely to accept jobs at which they are overqualified or underqualified. Glenda Quintini and Thomas Manfredi (2009) review school-to-work transitions in the United States and Europe. The transitions are characterized by different pathways taken by individuals in establishing themselves in the labor market, often involving frequent job changes and spells of unemployment. These frequent interruptions reflect underlying mismatches between workers and jobs upon entry into the labor market, and show that information on a worker's education does not fully characterize worker's qualifications for jobs. Highly educated individuals are likely to start out in jobs for which they are overqualified.

Ron Dekker, Andries de Grip and Hans Heijke (2002) find that overeducation contributes positively to career mobility in the professional and supplementary labor markets, but not in the internal labor market in which workers get

promoted at the firms where they are employed. They conclude that workers initially overeducated could use a first job in the supplementary labor market to gain training and move towards more suitable positions.

Wage losses for individuals The extensive literature on education and skill mismatches, summarized above in methods of observation and measurement, documents the wage consequences of mismatches in terms of education and skills, although their interpretation is uncertain.

Job satisfaction Dissatisfaction with work representatives an additional loss to workers from mismatches. Dissatisfied workers could also be less productive on the job and seek employment elsewhere more often. Survey data can be used to determine whether qualitative mismatches affect job satisfaction. In the European Community Household Panel, respondents are asked, "How satisfied are you with your present job in terms of the type of work?" Using responses to this question, OECD (2011b, p. 212; see also Quintini, 2011a, Annex 4.A6) estimates the effects of mismatches on job satisfaction using pooled regressions, with wage levels included. Comparing workers with the same qualification levels in different jobs, being overqualified reduces job satisfaction while being underqualified raises it. The effects are reduced using a random-effects model to control for unobserved individual heterogeneity.

Job training in response to mismatches George Messinis and Nilss Olekalns (2007a, 2007b) argue that workers respond to educational mismatches by getting training that modifies the consequences of overeducation and undereducation. Workers with inadequate education for their jobs get training in an attempt to get the same return as workers well-matched to the job. Using data from the 1997 Survey of Education and Training collected by the Australian Bureau of Statistics, they find that training brings wages for undereducated workers closer to the levels associated with the job. They argue that training also benefits overeducated workers by reducing the wage loss associated with their overqualification.

Job search and job mobility In general, overeducated workers have higher turnover rates (P. Sloane, H. Battu and P. Seaman, 1999). Wim Groot and Henriëtte Maassen van den Brink (2003) study the dynamics of mismatches in the Dutch labor market using data from the OSQ-Labour Market Survey. They estimate the likelihood of leaving or entering a condition of overeducation in a job, and conclude that the dynamics of movement are high. In the two year period studied, 40 percent left overeducation while five percent entered. They also observe that overeducated workers are about three times as likely to search for work as those who are not overeducated.

Recent OECD results (2011b, p. 213; see also Quintini, 2011a, Annex 4.A6, Table 4.A6.5) provide further evidence mismatched workers have greater job mobility. Using European Community Household Panel data, overqualified and

overskilled workers are more likely to engage in on-the-job search, while underqualified workers are less likely. Overskilling has a greater effect on job search than overqualification.

Based on interviews of businesses, Bewley (1999, p. 221) observes that 19 percent of businesses laid off workers because of technical change, 15 percent laid off workers because of reorganization of operations, and 12 percent laid off workers because of poor performance (61 percent laid off workers because of reduced sales, and 53 percent laid off workers because of financial distress; other causes are also listed). These observations support the conclusion that workers at jobs for which they are mismatched are more likely to experience layoffs. Layoffs caused by technical change and reorganization also contribute to technological obsolescence. Bewley also observes (1999, p. 329) that it is usually a waste of time for unemployed workers to look for jobs at too low a level, since they are likely to be rejected as overqualified.

Alfonso Alba-Ramírez and Maite Blázquez (2003) consider transitions among six different categories of mismatches using data from the European Community Household Panel for Spain. They find that overeducated workers have shorter job tenures than adequately educated workers. Workers with more than three years job tenure who are overeducated but whose formal training is closely related to their work are more likely to move to a different firm.

Using the HILDA (Household, Income and Labour Dynamics in Australia) survey data, Mavromaras, McGuinness and Wooden (2007) view job separation rates and outcomes for workers according to whether they are overskilled in their jobs. The HILDA survey provides five waves of data. Over the five waves, severely overskilled workers had on average a job separation rate of 28.4 percent, while well matched workers had a job separation rate of 17.1 percent (2007, Table 1, p. 310). However, the data indicate that improvement in skills match was slow (2007, Table 2, p. 311). Among workers who were severely overskilled in the first wage, only 30 percent were well matched by the fifth wave. The authors conclude that overskilling is not temporary and instead is a relatively persistent phenomenon (see also McGuinness and Wooden, 2007, and Mavromaras, McGuinness and Fok, 2009).

Promotion within firms Sandra Groeneveld and Joop Hartog (2004) investigate the likelihood that overeducated or undereducated workers get promotions or wage increases within a firm. Their data come from a single firm in the energy and telecommunications industry that has three major sections. One section, central staff, is primarily an internal labour market with little hiring from the labour market. Another section, commercial, employs workers through an external labour market in which workers face competition with workers outside the firm. Required education for different jobs is determined by the firm's hiring standards. Using personnel information from the firm, Groeneveld and Hartog estimate the likelihood of promotion and relative wage growth between 1995 and 1998. They find that being overeducated significantly increases both the likelihood of job promotion and wage growth, while undereducation has no

significant effects. Separating out data for the section with the internal labour market, undereducation additionally reduces job promotion significantly. For the section with the external labour market, the only significant effect is that overeducation increases the likelihood of promotions. Groeneveld and Hartog also observe differences with respect to age. With the combined data, overeducation significantly increases job promotion and wage growth for younger workers but not for older workers. The firm appraisal process will also affect the consequences of skill mismatches within firms by influencing the placement of individuals within the firm (CEDEFOP, 2012, p. 8).

Changes in likelihood of mismatch over career Wasmer et al (2007) find that overqualification declines with labor market experience, consistent with workers continuing to engage in job search to find a job that matches their qualifications. The percentage of workers that are neither overqualified nor mismatched increases with age. Nevertheless, there is substantial persistence in mismatches over a worker's career.

Among United Kingdom graduates, Peter Dolton and Mary Silles (2003) find that in initial employment, about half of university graduates are in jobs where they are overeducated, but after some time in the labor force, this falls to about one-fifth. Miller (2007), using Australian data, finds that overall overeducation declines with labor market experience. Korpi and Tåhlin (2009, p. 192) find no evidence that wage growth is lower or higher for mismatched workers, so that mismatched workers on average suffer on average a lower rate of return to schooling.

Skill obsolescence Andries de Grip and Jasper Van Loo (2002, p. 4) distinguish technical from economic skills obsolescence. Technical skills obsolescence arises from the natural aging process, illness or injury or insufficient or no use of skills. Economic skills obsolescence arises from new skill requirements, from declining employment in an occupation or economic sector, or from firm-specific skills lost as a result of worker mobility. Computerization, technological and organizational change, discussed in the next section on long run aggregate mismatches, provide a major explanation for the job-specific skills obsolescence that occurs to individuals. New technologies make certain skills redundant and at the same time create new ones (Allen and de Grip, 2007). Sherwin Rosen (1975) describes skills obsolescence caused by technological changes as vintage effects, reducing the value of human capital obtained earlier. Although aging is related to some forms of skills obsolescence, Lex Borghans and Bas ter Weel (2002) find that computerization does not differentially affect older workers, whose wages are not negatively affected by lack of computer skills. De Grip and Van Loo cite a number of studies that argue that higher levels of education protect workers against skills obsolescence, either because workers obtain secondary skills that they can still use, or because they can continue to maintain their skill levels through training (see 2002, Table 2, p. 16, for an overview of obsolescence studies). Lex Borghans and Andries de Grip (2000b) find that while new tech-

nologies allow highly skilled workers to continue employment, lower educated workers no longer have sufficient skills to keep their jobs. Sectoral shifts, as described by David Lilien (1982), also cause skills obsolescence and mismatches, by preventing workers from shifting to other sectors where their skills could be used. Skills obsolescence has often been measured by estimating wage effects in earnings functions, but worker skill surveys offer the opportunity to obtain objective measures.

Jim Allen and Rolf van der Velden (2002) use survey data to determine when job specific skill obsolescence occurs. They use data on Dutch graduates of tertiary education, who were asked "What percentage of the knowledge and skills that you acquired during (tertiary) education is now out of date?" They find that about 30 percent of skills are out of date, with a standard deviation of 21 percent. Since the respondents had graduated seven to eight years previously, the half-life of competencies lies between ten and fifteen years. Allen and van der Velden find that skills obsolescence is as likely to occur in generic as in specific fields of study.

Decline in cognitive abilities from mismatch Andries de Grip, Hans Bosma, Dick Willems and Martin van Boxtel (2008) study the consequences of job-worker mismatches for cognitive decline using longitudinal data on worker cognitive abilities from the Maastricht Aging Study. They consider the "use-it-or-lose-it" hypothesis, in which overeducated workers lose cognitive abilities over time, and the "intellectual challenge" hypothesis, in which workers who are challenged by working beyond their educational level experience less cognitive decline. The data provides an objective method of determining overeducation based on systematic job analysis. Measurement of cognitive abilities occurs at two points in time six years apart and covers verbal memory, cognitive flexibility, verbal fluency and information processing speed. De Grip et al also consider the hypothesis that overeducation occurs when workers lack cognitive skills for a particular educational level, so that overeducation compensates for lack of ability in a job. Contrary to this hypothesis, the authors find that the cognitive abilities of overeducated workers are not lower than workers with jobs that correspond to their educational levels. Also, workers in jobs that require higher levels of education do not have higher cognitive abilities. De Grip et al find that overeducation usually does not have significant effects on cognitive decline, although the magnitudes of the effects are high. However, when overeducation and undereducation are combined into a single job-mismatch variable, the resulting variable has a significant but mixed impact on cognitive changes. Also, risk of cognitive decline is lower at higher levels of education. A measure of extent of overeducation is significantly negatively related to immediate recall, delayed recall, and verbal fluency.

Mismatch Among Aging Workers Aging workers (over 50) are less likely to be overskilled than younger workers, but more likely to be overeducated (CEDEFOP, 2010c, p. 5). Although workers generally move over time to jobs

where they are better matched, skills obsolescence and cognitive decline may lead firms to place them in positions corresponding to their current skill levels. Mismatches among aging workers may generate fear of job loss or earlier retirement.

2.4.2 Losses for Firms

François Rycx (2010) provides direct evidence of the impact of educational mismatches on firm productivity. He first reviews the literature relating mismatches to productivity. Using human capital theory, one approach has inferred the effects of educational mismatches on productivity by observing the effects on wages and then assuming that wages correspond to productivity. A second approach observes the effects of educational mismatches on variables that are believed to be related to productivity, such as job satisfaction. These approaches yield different conclusions and impose methodological limitations. For example, Felix Büchel (2002) analyzes the effects of overeducation on productivity in Germany using data from the German Socioeconomic Panel. In contrast to results using United States data, Büchel finds that overeducation yields positive effects on productivity as measured by job satisfaction, health status, participation in on-the-job training, and job tenure. He argues that it is therefore reasonable for firms to hire workers that are overeducated for their positions.

Using firms as observations, Rycx estimates the effects of proportions of overeducated and undereducated workers on firm value added per worker using two linked Statistics Belgium data sets, the Structure of Earnings Survey and the Structure of Business Survey. The results indicate that firm productivity depends positively on the proportion overeducated and negatively on the proportion undereducated. Furthermore, by distinguishing workers that are younger than 36 or at least 36, Rycx concludes that the impacts of educational mismatches on productivity come from the younger workers. This is consistent with younger workers experiencing real mismatches, while older workers have levels of education that compensate for other productivity-related characteristics. Also, the result is consistent with the observation of Groeneveld and Hartog (2004) that overeducation increases job promotion and wage growth for younger workers. Rycx concludes that the results can be reconciled with the literature on wage effects of educational mismatches.

2.5 Policy Conclusions for Short Run Mismatches

There are a number of straightforward policy recommendations related to specific circumstances of qualitative mismatches. Since many workers are in horizontal mismatches, better guidance services would increase the likelihood of studying in a field related to a worker's job. This is also likely to reduce overeducation. Practices in New Zealand are cited as an appropriate system of career guidance (OECD, 2011b, p. 216). Second, raising the minimum level of competences (specifically numeracy and literacy) would reduce the likelihood of individuals seeking and getting jobs with insufficient skills. Both European

Commission benchmark goals for education and the U.S. No Child Left Behind Act have the intention of raising minimum levels of skills.

Policies can also target specific groups that experience mismatches. Young adults finishing their schooling face difficulties in making the transition to employment and often take short term jobs at which they are overqualified before finding stable employment (Quintini and Manfredi, 2009). Apprenticeships and dual labor programs in some countries substantially reduce the time taken to reach stable employment and consequently reduce the time spent in mismatches for this group. Immigrants face the problem that their qualifications are not recognized. For this group, a system that provides recognition of non-formal and informal learning would reduce the likelihood that immigrants end up in jobs for which they are overqualified or overskilled (OECD, 2011b, p. 215). For aging workers, policies of lifelong learning and on-the-job training can reduce mismatches caused by skills obsolescence and cognitive decline.

The causes of qualitative mismatches are closely tied to the features of the labor market that generate unemployment. Costly job search, arising from frictions and imperfect information about workers and jobs, leads workers to accept jobs that do not fully correspond to their qualifications, rather than continue to be unemployed. Employers choose workers that do not completely meet their job requirements rather than leave vacancies unfilled. As a consequence, the correspondence between worker and job characteristics will not be the same as in the optimal assignment, as reflected in qualitative mismatches. This link between qualitative mismatches, unemployment and vacancies shows up explicitly in the Gautier and Teulings model (2011) that estimates the costs of mismatches to be about the same magnitude as costs of unemployment and of vacancies. The immediate conclusion from this link is that policies that reduce unemployment will reduce qualitative mismatches, and vice versa.

Economists have attempted to explain differences in the unemployment rate between the United States and European countries in terms of the degree of flexibility in the labor market. Taxes at low income levels, the minimum wage, employment protection legislation, levels of unemployment compensation, and active labor market policies can affect how much mobility there is in the labor market and overall levels of unemployment. These institutional features can also be expected to affect mismatches, by affecting the decisions of workers to accept jobs and employers to make offers to workers. Fabian Slonimczyk and Peter Skott (2012) argue that monopsonistic effects arise when firms prefer low skill workers for low tech jobs rather than overeducated high skill workers. Then an increase in the minimum wage would raise employment of low skill workers along with aggregate employment and would also reduce wage differences. Wasmer et al (2007) argue that employment protection legislation increases the incidence of mismatches as well as increasing unemployment levels.

3 Long Run Qualitative Mismatches

Currently the United States is experiencing a long run aggregate qualitative mismatch between demands for college-educated labor and supplies, as suggested by increases in the relative wages of college graduates. How did changes in jobs and the labor force contribute to this qualitative mismatch? What prevented the labor force from fully adapting to future changes in jobs? To what extent did this qualitative mismatch occur in other economies? Fortunately, in an attempt to explain rising inequality and increasing educational premiums, extensive economic research has focused on the generation and explanation of the current qualitative mismatch. This research is reviewed here. Possible causes include technology, the spread of computerization, globalization, organizational change, and changes in the education provided to and chosen by individuals. Consequences of long run aggregate qualitative mismatches include missed investment and employment opportunities, job polarization and inequality. Eventually, long run aggregate qualitative mismatches would decline, perhaps to be replaced by new mismatches, as the extent of the mismatch is recognized and individuals react to it. Losses from the mismatch would be reduced by early recognition and development of appropriate policies. The section considers future changes in job requirements as well as policies that can help an economy to adapt to change.

3.1 Causes

Technological change, consumer preferences and trade alter the mix of jobs in an economy over time. As a result of the development of new products by firms and the development of new consumer needs, the products produced today in a country differ from the products produced a few decades ago. New production procedures displace older processes that used earlier sets of worker skills. Simultaneously, individuals choose types of education (e.g. occupations, trades, and industries) and levels of education based on their incentives, opportunities and expectations. New generations of workers come to the labor market while older generations retire, with new skills, career goals, and attitudes about work. Long run aggregate qualitative mismatches arise when over time the mix of requirements for jobs in an economy differs from the mix of qualifications that individuals have obtained in preparation for employment.

In addition to the qualitative mismatch examined by economists studying the recent increases in educational premiums and mismatches, other episodes of qualitative mismatches occurred in the past and illustrate how they arise. In their discussion of the high school movement, Claudia Goldin and Lawrence Katz describe the growth of office jobs in the early twentieth century that arose as the result of the reorganization of production and distribution (2008, p.172). This growth generated extremely high returns to training for office work (2008, p. 181) and endogenous technological change in the development of office equipment. The high returns to office work, as well as the high returns to blue collar manufacturing workers with high school training, provided communities with an

impetus to provide high school education and generated incentives for individuals to acquire high school education. In this case, the qualitative mismatch arose both from changes on the demand side and from the inability to anticipate the changes that would take place. As a result, the growth of high schools lagged the demands for high school workers but gradually eliminated the qualitative mismatch and reduced the high school premium over time.

Trade in grain in the nineteenth century generated another qualitative mismatch. As a result of transportation development in the United States, large quantities of grain were exported to Europe, depressing prices of grain. This generated substantial movement of farmers and resources out of grain production and either into other forms of food production or out of agriculture altogether (T.K. Derry and Trevor I. Williams, 1960, p. 685). Continental European countries (which also imported grain from Russia and the Ukraine) were affected less severely because they imposed tariffs, unlike the United Kingdom. Denmark responded to lower grain prices by emphasizing a high level of rural education through the folk high school movement (Derry and Williams, 1960, p. 686). Denmark also moved towards cooperative forms of production that disseminated technological change such as the mechanical cream-separator.

A third episode arose in the different responses of England and Germany to the rapid technological change in the last two decades of the nineteenth century. German advances in chemical and electrical manufacturing arose from cooperation between industry and university research departments and on a planned network of technical institutes and trade schools that provided trained workers with scientific backgrounds (Derry and Williams, 1960, p. 703). In Saxony, there was one technical school per 10,000 individuals, and chemical manufacturers had on average one university-trained chemist per forty workers (Derry and Williams, 1960, p. 308). In contrast, insufficient attention was placed on science at Oxford and Cambridge, Britain lacked the technical colleges developed in Germany and France, and their Mechanics' Institutes failed to develop because of inadequate elementary education (Derry and Williams, 1960, p. 704). This episode shows that educational policy responses to technological change can exacerbate or ameliorate qualitative mismatches.

3.2 Observation and Measurement of Long Run Qualitative Mismatches

This section considers three methods of observing and measuring long run qualitative mismatches. The first method observes mismatches indirectly through their consequences for relative wages of different categories of workers. Increases in the wages of more educated workers relative to less educated workers provides an example of the first measure and has provided the major motivation for the study of long run qualitative mismatches. A second method arises by examining consistently measured changes in mismatches observed at the individual worker-job level. For example, a decline in overeducation would suggest that supplies of educated individuals had grown less rapidly than demands for them. A third approach draws inferences from changes in the relative shares of

income going to skilled and unskilled labor for the relative shifts in supply and demand that generate long run mismatches. These methods are considered here in order. All the methods point to significant differences in the evolution of long run qualitative mismatches between the United States and European countries.

3.2.1 Changes in Relative Wages

The fundamental method of studying these long run qualitative mismatches is shifts in supply and demand for different combinations of job characteristics. The relative size of these shifts can be observed indirectly through their effects on the wage rates for different groups of workers. For example, consider a very simple version of the labor market in which workers are either skilled or unskilled, and production requires combinations of skilled and unskilled workers. Suppose the market for unskilled labor is stable over time, with changes in the numbers supplied or demanded growing at the same rate. In the market for skilled labor, two alternatives are possible. In the first alternative, shown in Figure 6, the supply curve shifts further to the right than the demand curve, generating a decline in the wage rate for skilled labor and a decline in the wage premium (the wage for skilled labor relative to the wage for unskilled labor). In the second alternative, shown in Figure 7, the demand curve shifts further to the right than the supply curve, and the wage rate for skilled labor and the wage premium increase. In Jan Tinbergen's characterization of the evolution of income distribution, technology is constantly shifting the demand curve for skilled labor to the right, and educational institutions are always shifting the supply curve to the right. Whether the wage premium for skilled labor and income inequality increases then depends on the race between technology and education. In Figure 6, education wins and inequality declines. But in Figure 7, technology wins and inequality increases.

The motivation for the study of the recent qualitative mismatch for skilled and educated labor in the United States has been the steeply rising college premium and increasing inequality. Goldin and Katz (2008, p. 290) derive changes in the college graduate wage premium and the high school graduate wage premium. These premiums declined from 1915 to about 1950. The college graduate premium then rose strongly, declined in the 1970's, and thereafter continued to rise until, by 2005, it had reached the high levels it started from in 1915. The high school premium (comparing high school graduates with individuals having only an eighth grade education) shows a similar decline from 1915 to 1950, followed by a stable premium from 1950, and thereafter a slightly increasing premium to 2005. The increase in the educational premiums identified by Goldin and Katz and others suggest that the situation resembles the result in Figure 7, but does not by itself identify whether the increase occurs because of a greater rightward shift in demand or a smaller rightward shift in supply.

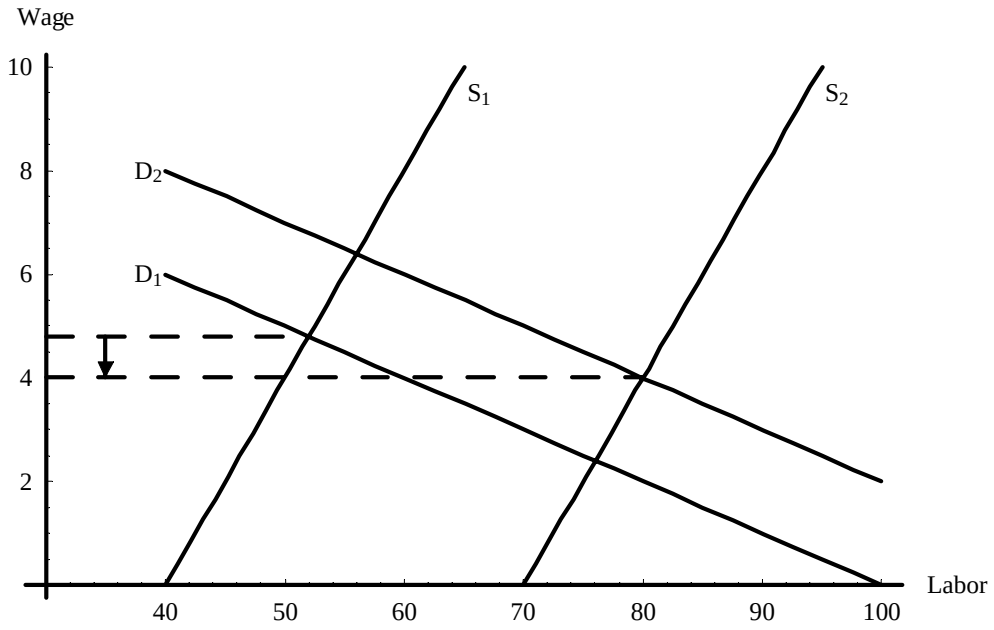

Figure 6: Wage Decline When Demand Shifts Less Than Supply

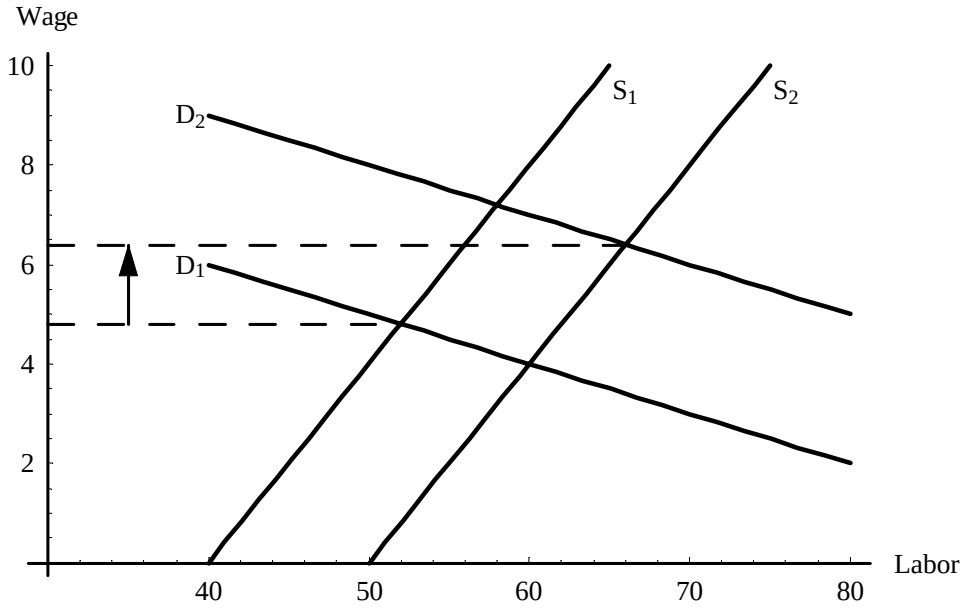

Figure 7: Wage Increase When Demand Shifts More Than Supply

3.2.2 Changes in Qualitative Mismatches at the Individual Worker-Job Level

Long run aggregate qualitative mismatches generated by the factors considered above can be expected to affect the levels of short run individual qualitative mismatches observed at a point in time. An increase in numbers of individuals with higher levels of education relative to the educational requirements of jobs would generate, through the job and employee search process, an increase in the number of individuals that are overeducated for their jobs and a decrease in the number that are undereducated. However, labor markets may also adapt to shifts in supplies and demands in ways that would reduce effects on overeducation or undereducation. With hierarchical assignment, an increase in educational levels of workers would generate a new assignment in which workers ended up in jobs with lower educational requirements.[14] Peter Dolton and Mary Silles (2003) argue that firms may react to grade inflation by upgrading the educational requirements for jobs, in order to get the most able graduates (see also A. Chevalier, 2003). To the extent that job requirements respond quickly to shifts in supply and demand, long run aggregate mismatches arising from such shifts would not be reflected in individual worker-job mismatches. However, Hartog (2000) has observed that updates to the Dictionary of Occupational Titles occur infrequently, so that shifts in supply and demand would be reflected in individual worker-job mismatches using the job assessment approach. Also, an oversupply of individuals with higher levels of education may lead to substitution among forms of human capital that would reduce the effective level of overeducation. A potentially complicating factor is that even neutral changes in labor demands could have asymmetric effects in markets. Peter Skott (2006) has shown that in the presence of efficiency wages, neutral shocks would lead unemployed high skill workers to seek low skill jobs. Non-shirking conditions would then induce overeducation in the low skill market, reducing employment and relative wages of low skilled workers.

Although the connection between long run aggregate qualitative mismatches and levels of individual worker-job mismatches deserves further examination, it is reasonable that there would be some connection. Observations on patterns of overeducation and undereducation over time would therefore provide additional information on causes of changes in long run qualitative mismatches. Collecting results from different sources, Hartog (2000, p. 134) presents evidence from previous studies on overeducation and undereducation for separate years based on job analysis (JA) or worker self-assessment (WA), summarized in the following table to show changes:

[14] Educational upgrading of jobs is described further by M. Quinn and S. Rubb, 2006; EENEE, 2008, p. 19; and CEDEFOP, 2010b, p. 59.

Table 11: Changes in Overeducation and Undereducation Over Time

Country	Period	Method	Overeducation	Undereducation
Netherlands	1960-1977	JA	Up from 7% to 26%	Down from 36% to 21%
Netherlands	1974-1995	WA	Up from 17% to 24%	Down from 30% to 12%
Spain	1985-1990	WA	Up from 17% to 28%	Down from 23% to 11%
Portugal	1985-1992	JA	Up from 26% to 33%	Down from 43% to 38%
U.S.	1969-1977	WA	Down from 35% to 32%	Not Available

Source: Hartog (2000)

Hartog suggests that the evidence for the Netherlands, Spain and Portugal reflect an increase in supplies of educated workers relative to demands. For the United States, the results indicate the opposite, with a decrease in supplies of educated workers relative to demands. The overeducation and undereducation results cited in Hartog are limited in the span of time covered and do not cover recent years. Also, evidence on undereducation for the United States is absent. However, the conclusion for the United States is supported by Mary Daly, Felix Büchel and Greg Duncan (2000, p. 173). Using the Panel Study of Income Dynamics, they find that overeducation declined between 1976 and 1985 from 38.5 percent to 31.8 percent for men and from 36.8 percent to 33.5 percent for women. Over the same time periods, undereducation rose from 16.3 percent to 21.2 percent for men, and from 11.3 percent to 16.8 percent for women. Peter Gottschalk and Michael Hansen (2003) also find that the proportion of college graduates in noncollege jobs has declined. Assuming that the factors influencing labor demands are common for the United States and European countries (skill-biased technological change, capital-skill complementarity, skill-biased organizational change, computerization), a decline in overeducation in the U.S. compared to European countries would suggest that the source of the difference is the slowdown in growth of educational levels in the United States as argued by Goldin and Katz. The results also show that long run aggregate qualitative mismatches have consequences for individuals through increased or reduced likelihood of being in mismatches.[15]

In an analysis of changes in mismatches over time for Portugal, Hartog (2000, p. 144) concludes that the consequences for the returns to education cannot be reflected in a simple supply and demand model. Instead, it is necessary to look at changes in dispersion of requirements on the demand side relative to dispersion in education on the supply side. This observation supports the use of assignment models and foreshadows the Acemoglu and Autor (2012) criticism of the canonical supply and demand model used by Goldin and Katz and others

[15] Using Current Population Survey data, Fabián Slonimczyk (2012, Figure 3) observes the opposite pattern, with overeducation rising in the United States from 15.6 percent for males in 1973 to 33.5 percent in 2002. Over the same period, undereducation declined from 21.8 percent to 8.9 percent. These different results need to be resolved.

(considered below).

For the Netherlands, Berkhout, Van der Werff and Heyma (2010) provide estimates of vertical and horizontal mismatches between 1996 and 2005. They find that there was a slight increase in mismatch among higher educated workers in the period considered. For middle educated workers, they found no trend.

Jean-François Giret (2007) provides a long time-series of overeducation from 1981 to 1997 based on the French Labour Force Survey. Overeducation is measured at different educational levels, with the measure of overeducation taken 3 years after leaving school. CAP (for Certificate of Professional Competence) and BEP (for Vocational Studies Certificate or Vocational Baccalaureate) are diplomas at the secondary education level. France experienced a rapid expansion of student numbers in the last decades of the twentieth century. This growth in supply is reflected in the levels of overeducation. Overeducation increased more than 10% at all school levels. The growth in overeducation was greater during the 1990's in the presence of a recession. These results support the conclusion that a long run shift in the balance between supplies and demands (generated in the case of France by the growth in supplies of educated and trained workers) is reflected in the individual worker-job incidence of overeducation, and that a recession contributes to that incidence.

3.2.3 Measurement Based on Income Shares

Marco Manacorda and Barbara Petrongolo (1999) develop an empirical index of skill mismatch based on economic inferences from both wage and employment variables. They assume a standard (Cobb-Douglas) production function with two types of inputs, skilled and unskilled labor. In this production function, the parameter for an input will be the input's income share of production. Manacorda and Petrongolo assume that technological change takes the form of changes in these parameters (this differs from the representation of technological change discussed in the section on skill-biased technological change but resembles the representation used by Tinbergen, 1974). Their mismatch index is given by the proportional change in input shares minus the proportional change in employment (1999, equation 4, p. 189). The index can reflect either supply or demand shocks. If this index is zero, the changes in demands for the two skill types are exactly matched by the changes in supplies, and the net impact is neutral. A positive mismatch index for skilled labor reflects skill-biased technological change. A given level of the mismatch index is resolved into either relative wage changes or relative unemployment changes for the two groups, depending on wage-setting institutions in a country. Manacorda and Petrongolo calculate the mismatch index for OECD countries based on estimates of the production functions for each country. Table 12 summarizes their results. Their measures (1999, Column 5, Table 2, p. 192) indicate that there have been shifts against the unskilled (and for the skilled) in Britain, France, and Germany over the periods considered, virtually no shift for Italy, and shifts against the skilled in the Netherlands. For the United States, there was a substantial shift in favor of skilled labor in the 1980's, apparently caused by a slowdown in the supply

of skills rather than an acceleration in demand. This observation supports the Goldin and Katz view of the causes of increases in the U.S. college premium, discussed in the following section among other explanations.

Table 12: Growth in Net Relative Demand for Skilled

Country	Period	Net Relative Demand	Outcome
France	1984-1994	0.36	Substantial shift against unskilled
Britain	1974-1992	0.73	Substantial shift against unskilled
Germany	1976-1989	0.58	Substantial shift against unskilled
Italy	1977-1991	0.06	Virtually no shift
Netherlands	1979-1993	-1.08	Substantial shift against skilled
Sweden	1970-1979	0.41	Substantial shift against unskilled
U.S.	1970-1979	-1.11	Substantial shift against unskilled
U.S.	1979-1989	1.48	Substantial and greater shift against unskilled

Source: Manacorda and Petrongolo, 2009, Table 2

Manacorda and Petrongolo consider Paul Krugman's argument (1994) that increasing unemployment in Europe and increasing wage differentials in the United States are simply alternative responses to the same underlying cause, a relative shift in demand favoring more skilled workers. Their model is consistent with Krugman's view, since either increasing wage differentials or greater unemployment could arise from a given skill mismatch. Manacorda and Petrongolo combine their skill mismatch index with assumptions regarding wage determination to explain the generation of unemployment for different skill groups. They assume that a skill group's wage rate depends on a measure of its wage pressure factors, the responsiveness of the group's wage to its unemployment rate, and the group's unemployment rate. The parameters of this relationship can vary among skill groups and among countries. Manacorda and Petrongolo conclude that, except in the United States and Britain, skill mismatch could not have explained all of the increase in unemployment of the unskilled, and there must also have been some increase in wage pressure. In Britain, mismatch explains more than half of the growth in unskilled unemployment, while in the United States skill mismatch can explain all of the growth.

3.3 Methods of Analysis

Sharply increased levels of inequality in recent decades have been documented for the United States and other countries. Social scientists have sought to explain increases in inequality caused by phenomena that would generate greater shifts in demands for skilled workers than have occurred in the past. This section

proposes several different explanations for what happened in the race between education and technology to generate the qualitative mismatch. Capital-skill complementarity, skill-biased technological and organizational change all provide explanations based on significant shifts on the demand side, assuming that changes on the supply side have continued as before to increase the numbers of educated and skilled workers. Globalization, operating through immigration and trade, does not appear to provide a major explanation for the current increases in educational premiums, although offshorability is clearly relevant to future qualitative mismatches. Goldin and Katz argue that the source of the qualitative mismatch lies on the supply side, in the form of a substantial slowdown in the accumulation of human capital in the United States (see also supporting evidence in Pedro Carneiro and James Heckman, 2003, p. 86). In particular, Goldin and Katz argue that skill-biased technological change occurred throughout the twentieth century (2008, p. 92), so that there was no acceleration in the bias that would generate a relative demand shift.

3.3.1 Capital-Skill Complementarity

A central feature of processes that produce goods and services is the extent to which using more capital (structures, machines and equipment) will allow a firm to reduce the number of workers needed. When capital can be easily substituted for worker's labor, a firm's use of capital is very sensitive to the prices of capital and labor. Economists measure how easily capital can be substituted for labor by the elasticity of substitution. Capital-skill complementarity can arise when a production process uses three factors of production (for example, capital, raw labor and skilled labor) instead of just two.

Zvi Griliches (1969) introduced the concept of capital-skill complementarity to explain how increases in capital could raise the demand for skilled labor relative to the demand for raw labor. Then the process of capital accumulation in advanced economies by itself generates greater requirements for skilled workers over time, and greater inequality through its effect on skilled labor's wage premium (the higher wage paid to skilled labor over what is paid to unskilled labor).

Per Krusell, Lee E. Ohanian, José-Víctor Ríos-Rull, and Giovanni L. Violante (2000) examine whether capital-skill complementarity, in combination with changes in factors of production, could explain observed patterns of skill premiums in the United States (see also Fallon and Layard, 1975). They distinguish between capital structures and capital equipment, and observe that the growth of capital equipment has accelerated since the 1970's. Their main finding is that observed changes in amounts of capital and labor can explain most of the changes in skill premiums over a 30 year period, even in the absence of technological change that would increase skill premiums. The underlying cause of changes in the distribution of job characteristics would be the relative decline in the price of capital equipment.

3.3.2 Skill-Biased Technological Change

Considering the many ways that computers and information technology have transformed our workplaces, skill-biased technological change (hereafter SBTC) is extremely appealing as an explanation for increased relative demands for skilled workers. John Hicks (1932) introduced the concepts of technological change to explain how progress would affect labor and capital, treated as aggregate, homogeneous factors of production. Technological change would be biased in the form of capital using or labor using depending on whether the relative expenditure on capital increases or decreases at the current capital to labor ratio, and would be neutral if the relative expenditure is unaffected. Roy Harrod (1956) developed a classification based on what happens after the economy adapts to the technological change. These concepts can be applied to demands for skills by extending the list of homogeneous factors to include aggregate skills in addition to raw labor, or by including unskilled labor and skilled labor separately.

Daron Acemoglu (2002) surveys skill-biased technological change.[16] Technological change occurs by expanding the effective amounts of skilled and unskilled labor. Depending on how easily skilled and unskilled labor can be substituted for each other, technological change that augments skilled labor will increase the skill premium, given by the wage of a skilled worker divided by the wage of an unskilled worker. This type of technological change would then be skill-biased. Acemoglu also emphasizes that the direction of bias of technological change responds to profit opportunities, and that an expansion of skilled labor in the economy could generate skill-biased technological change.

Arnaud Dupuy and Philip S. Marey (2008) examine SBTC in the context of an assignment model. As in the standard literature, SBTC changes the relative efficiencies of skilled and unskilled labor. However, it can also change how easily different types of labor can be substituted for each other. Both changes in relative efficiency and the ease of substitution are involved in the determination of wage differentials. Using U.S. data from the Current Population Survey, Dupuy and Marey find support for the argument that the substitution between types of labor has changed over time. By considering technological changes in relative efficiency and substitution among types of labor, they explain both changes in wage differentials and the rate of change of labor productivity.

In a development related to Costinot and Vogel (2010), Acemoglu and David Autor (2011) formulate a tractable assignment model that explains consequences of different types of changes on the supply and demand side. A shortcoming of models based on a few aggregate homogeneous factors of production (specifically capital, skilled labor, and unskilled labor) is that they can only explain a single skill premium. In contrast, labor markets exhibit different behavior of educational premiums at different educational levels. For example, in the United States, wages of low-skilled labor have fallen, job polarization has oc-

[16] See also Eli Berman, John Bound and Stephen Machin, 1998, Machin and John Van Reenen, 1998, and Gilles Saint-Paul, 2008. Arnaud Dupuy, 2008, reviews technological change in the context of an assignment model.

curred (in the form of increases in employment of high-skilled and low-skilled workers relative to middle-skilled workers), and offshoring of jobs occurred at different intervals of the job spectrum. In the Acemoglu and Autor model, a range of tasks contributes to final output. They assume a simplified version of the continuous Cobb-Douglas production function used in Sattinger (1980, p. 227) to generate the demand for a continuum of workers in an assignment problem. Their model is also included in their review of Goldin and Katz (Acemoglu and Autor, 2012) using a continuous Constant Elasticity of Substitution production function. Workers are of three types: high, middle or low. Applying the standard comparative advantage assumption (higher groups have a comparative advantage at higher tasks), it is possible to determine the assignment of workers to tasks consistent with competitive markets. The solution is characterized by the threshold tasks at which types of workers change from low to medium and from medium to high. Technological change that augments the productivity of high skilled workers generates a reassignment of workers to tasks that can be determined from the model, with consequent changes in the wages of the three groups. Offshoring takes the form of a subinterval of tasks performed by individuals outside the country, resulting in reassignments of workers within the country to maximize production. The model also describes what happens when capital replaces workers previously performing a subinterval of tasks. The model provides a general method for analyzing changes in demands for different types of workers.

3.3.3 Computerization

Much of the argument favoring skill-biased technological change is based on the belief that widespread computerization has altered the skill content of jobs in a manner that favors workers with greater skills or education. David Autor, Frank Levy and Richard J. Murnane (2003) apply a disaggregated analysis to examine consequences of computerization for the skill content of jobs over time. They argue that computer capital substitutes for workers engaged in routine tasks and helps workers carrying out non-routine tasks. To analyze demands for routine and non-routine labor inputs, they assume a production function in which routine labor inputs and computer capital are perfect substitutes, and output is generated by a standard production function that uses non-routine labor input and the sum of routine labor input plus equivalent computer capital. This assumption about production generates predictions of the responses for labor demands to declines in the price of computer capital. To test these predictions, Autor, Levy and Murnane obtain data on the skill content of jobs from the United States Dictionary of Occupational Titles. Indicators of non-routine tasks include Direction, Control and Planning (DCP) and quantitative reasoning requirements (GED-MATH). Routine cognitive tasks are indicated by a variable STS, for Set Limits, Tolerances, or Standards. Routine manual tasks are measured by a variable for finger dexterity. A fifth variable, for eye-hand-foot coordination, indicates non-routine manual task requirements. Combining the DOT data with samples from the Census and Current Population Survey,

the authors distinguish two sources of shifts in the skill content of U.S. jobs. The first, described as an extensive margin, arises from changes in the occupational distribution of employment, which would lead to changes in the aggregate skill content of labor demands even without any changes in the skill content of individual jobs. The second source, described as the intensive margin, arises from changes in the skill content of occupations over time. In support of their hypothesis regarding the relation between computer capital and routine and non-routine labor, Autor, Levy and Murnane find that routine labor inputs declined while non-routine labor inputs rose; shifts towards non-routine labor were greater in rapidly computerizing industries and occupations; and the shifts towards non-routine labor were pervasive at all task levels.

Francis Green, Alan Felstead and Duncan Gallie (2003) analyze changes in skill requirements for jobs as a result of computerization directly from responses to consistent survey questions in 1986, 1992 and 1997. They cite methodological problems in using occupational status or educational attainment to observe changes in skill requirements and argue that responses to the survey questions provide more detailed information. They conclude that increases in job skill requirements are strongly related to computer usage, and that the increases were more rapid for women than for men. Skills did not rise more quickly in industries that faced greater trade.

Levy (2010; see also Levy and Murnane, 2005) provides more detail on the kinds of work that can and cannot be taken over by computers. Levy observes that technology changes the nature of work faster than people can change their skills, making it hopeless to list future occupations. Instead, it is possible to identify the skills that future occupations will use. Computers can substitute for humans when the information needed is in a form that can be used by a computer, and when the processing of the information can be expressed in terms of rules. Often, however, an individual needs to engage in complex communication to discover the relevant information, for example when a doctor speaks to a patient or a teacher tries to find out whether a student understands a point. Complex communication differs from exchange of data because the information needs a wider context to be interpreted, and computers are limited in going beyond the data itself. The second area where computers are limited is in expert thinking, where a problem cannot be solved by applying fixed rules but instead a solution path must be found based on recognition of patterns from previous cases.

Stuart Elliott (2007; see also discussion in Hilton, 2008) develops a pilot project to forecast impacts of computers in 2030. The approach looks forward to future uses of computers instead of backwards to determine past consequences of computerization for the labour market. In this view, labour market tasks taken over by computers would not be limited to simply routine tasks as considered by Autor, Levy and Murnane (2003). In Elliott's procedure, he first uses O*NET to determine the human abilities that are relevant to work. The human abilities are sorted into four groups: language, reasoning, vision and movement. He then reviews articles in the computer science literature to see how much computers will be able to do within these four groups. The third

step is to consider which occupations have abilities that could be taken over by computers. The non-automated occupation mix then determines the future distribution of skills needed in the labor force.

In language, computers would be able to handle the medium level of difficulty in the O*NET scale. Computer reasoning depends on whether common sense can be incorporated into knowledge databases. With this development, Elliott concludes that computer capabilities will lie between medium and high. Vision and movement abilities would lie between low and medium. Overall, by 2030, about 60 percent of employment would be displaced by computers (Elliott, 2007, Table 8). The displacement ranges from 6 percent for legal work to 93 percent for sales and related (education, training and library is displaced by 74 percent). In Table 9, Elliott provides the ability distribution across the four groups for the labor force in occupations that are not displaced. The following table compares percentages above a specified ability level between 2004 (from U.S. Bureau of Labor Statistics) and the 2030 projections for the labor force not displaced by computers for each of the four groups. For example, in 2004, 15 percent of jobs used reasoning levels at level 5 or higher in the O*NET system. Subtracting out the jobs that computers will be able to do in 2030, 36 percent of jobs will require reasoning levels at 5 or higher.

Table 13: Projected Changes in Computer Ability Levels

	Language	Reasoning	Vision	Movement
O*NET Ability Level	≥ 5	≥ 5	≥ 4	≥ 4
Percentages in 2004 (BLS)	21%	15%	17%	18%
2030 Projections	52%	36%	44%	45%

Source: Elliott (2007)

The implications of this analysis for qualitative mismatches is that computerization, or the price of computer equipment and computation, would be a significant variable explaining shifts in demands for different types of labor in different countries.

3.3.4 Globalization

Globalization affects demands for different types of workers through trade, outsourcing and offshoring. Continuing declines in costs of goods transportation and information transmission together with formation and strengthening of trade unions and pacts along with reductions in tariffs and quotas will generate greater trade in goods and services. Reduced barriers to migration will change supplies of different types of workers. Technological change, by breaking down the labor processes and production steps, will expand opportunities for trade according to comparative advantage in the form of outsourcing and offshoring.

Consequences of trade and migration for demands for workers have been examined in the literature on income distribution. Richard B. Freeman (2009) describes three major consequences of globalization for future labor markets. The first is the approximate doubling of the number of workers in the world market economy as a result of the shift to markets in China and the former So-

viet bloc, and India's market reforms. While the labor force available for world market production doubled, the available world capital stock did not, generating a fall in the global capital to labor ratio. With unequal ratios of capital to labor around the world, there are incentives to move capital to areas where it is more productive, or to combine labor from populous areas with capital in advanced economies. Second, improvements in information and communication technology expand the scope over which market forces can operate. The third element that expands globalization's effects is the more rapid dissemination of knowledge and technology from advanced to developing economies, disproportionately increasing the participation of the newer world economy members in highly technical industries.

While trade, migration and outsourcing have long been elements influencing supplies and demands for workers, offshoring is relatively new and offers the greatest prospect for changes in future labor markets. Alan Blinder argues that offshoring is a "big deal," and that in the United States 30 to 40 million jobs are potentially offshorable in the next few decades (2009, p. 37). Offshoring occurs when a firm's jobs are moved out of the firm's country. A common example would be call centers for a firm's products staffed by individuals in another country. Offshoring of these services has been made possible by improvements in communication combined with rapid declines in communication and information transmission costs. Blinder bases his estimate of the extent of offshorability on characteristics of jobs as listed in the O*NET, the successor to the Dictionary of Occupational Titles developed by the U. S. Bureau of Labor Statistics. In his "subjective" measure, offshorability depends positively on whether services can be delivered to a remote location without being severely degraded, and negatively on the importance of personal face-to-face contact and the requirement that a service be performed at a specific location. Continuing changes in information and computing technology can be expected to extend the range and complexity of services that are offshorable. The large job losses for the United States will continue for decades and generate substantial transition effects (2009, p. 32). Blinder also argues that the United States and the United Kingdom face more offshoring than Europe because of India's comparative advantage in services in English. Lori G. Kletzer develops an alternative index of offshorability that is consistent with Blinder's estimate of 30 to 40 million (2009, p. 89). Alan Blinder and Alan Krueger (2009) compare alternative measures of offshorability, including self-reporting and professional coding. All measures indicate that about 25 percent of U.S. jobs are offshorable.

In addition to the large transitional employment effects, offshorability will have a compositional effect on jobs that differs from the effects of capital-skill complementarity or skill-biased technological change on relative demands for more skilled or educated workers. The criterion of offshorability cuts across educational levels and can include white-collar professionals such as radiologists (Levy and Yu, 2006). Kletzer (2009, p. 89) observes that there is a positive correlation between educational level and offshorability (for example, economists' services are offshorable, but bartenders' services are not).

The contribution of offshoring to future demands for workers and qualita-

tive mismatches could be determined by applying indices of offshorability to the job mix of different countries, taking into account the effects of languages on offshorability. OECD provides estimates of job losses from offshoring and outsourcing for OECD countries (2007).

3.3.5 Organization of Work

Although technological change is usually characterized as taking place through a given production function (for example in terms of augmenting the amounts of factors available), it also affects the process of production itself, and thereby changes how work is organized and the characteristics of workers that contribute to a firm's output.

Paul Milgrom and John Roberts (1990) describe changes in manufacturing that affect the organization of work and the activities of workers. Advanced manufacturing involves flexible machine tools and programmable, multi-task production equipment instead of specialized, single-purpose equipment used in mass production. These advances allow a much wider product line with individual items produced in small batches, involving shorter production cycles, less work-in-progress, speedier response to demand fluctuations or changes in customer requirements, and increased emphasis on fewer defects. In terms of employee activities, these changes lead to a parallel, team approach to design and marketing, a redefinition of worker responsibilities, and multiple responsibilities for individual workers (for example, production and quality inspection). Increased flexibility of productive assets reduces the marginal value of governance activities, so that manufacturing organizations have fewer layers of governance.

Assar Lindbeck and Dennis Snower (1996) also describe the organizational changes taking place in firms. Unlike traditional hierarchical production, activity occurs in teams that report to a central management with few intervening organizational layers. Production processes have been transformed through the application of computers, use of flexible tools, and programmable equipment that can perform multiple types of tasks, yielding greater flexibility in production. Computers allow more individualized treatment of employees and customers and decentralized decision-making, and enable employees to perform multiple tasks while exploiting complementarities among them. Firms are able to offer broader product lines in smaller quantities in response to customer requirements, leading to greater customer participation in product design and greater emphasis on product quality and ancillary services. The nature of work is also changing, with occupational boundaries breaking down in favor of multi-tasking and work rotation. Lindbeck and Snower describe the firm's decision in allocating tasks to workers. Depending on how much a worker's knowledge of one task helps in another task, the firm may choose complete specialization or multi-tasking. This decision is affected by information technology, production technologies that affect how tasks are related, and the human capital of workers.

Eve Caroli and John Van Reenen (2001) consider Skill Biased Organizational Change (SBOC). Organizational change takes the form of decentralization of authority, reduction in managerial layers, and increased multi-tasking.

As authority is decentralized, the managerial hierarchy gets flatter. They formulate three empirical predictions concerning organizational change. Under the assumption that organizational change is complementary to skills, it would lead to a fall in the demand for less skilled labor. Second, since organizational change is more costly when skilled labor is relatively more costly, a fall in the relative cost of skill will lead to more organizational change. This reflects the endogeneity of organizational change. Third, organizational change will have a greater impact on workplaces with higher skill levels. They find empirical support for these predictions using British and French data on organizational changes.[17]

These observations on the organization of work carry strong implications for the worker skills and characteristics that will be required in the future. Employees will need to engage in multi-tasking, often engaging in activities that combine production with management. For example, just-in-time inventory systems require not only that goods be produced, but that they be available at a particular point in time and without defects. Quality and time add management dimensions to the activities of production workers. Employees will also work in teams to coordinate the requirements of customer, production and marketing constituencies, placing greater emphasis on communication skills. Increasing variety of products in small batches places greater emphasis on innovation to find new products and services for customers. These developments affect firm recruitment policies, generating potentially new categories of mismatches between workers and firms.

3.3.6 Supplies of Workers

Supplies of workers occur in response to individual incentives to invest in human capital combined with educational institutions and public policies in support of education and training for different types of workers. In explaining increases in the college premium in the U.S. over the last few decades, researchers analyzing the problem have combined an economic basis for increases in demands with a characterization of changes in supplies. David Card and Thomas Lemieux (2001) identify increases in college to high school wage differentials for young men aged 26 to 30 in the U.S., U.K. and Canada and attribute the increases to the slowdown in growth of educational attainment for younger workers. Goldin and Katz (2008) provide perhaps the most thorough analysis of supply changes, covering not only the last few decades but the history of education in the United States from the nineteenth century on.

Goldin and Katz argue that the United States led European and other nations at various stages in the advancement of education and training. These include the common school crusade (2008, p. 142), which substantially increased enrollments through the age of about 14 by the 1870's; the high school movement (Chapter 5, p. 163), which provided secondary education to a majority of students by 1940; and mass higher education (Chapter 7, p. 247), which initially

[17] See also Timothy Bresnahan, Erik Brynjolfsson and Lorin M. Hitt, 2002; Thomas K. Bauer and Stefan Bender, 2004; Frederick Guy and Peter Skott, 2008; and Borghans and ter Weel, 2006.

provided the United States a lead in college education. However, these advances in supplies of workers did not continue after about 1980. For cohorts who turned 24 between 1900 and 1975, average years of schooling increased by .82 years per decade (2008, p. 19). For the years 1975 to 1989, the change was negligible, and in the decade between 1989 and 1999 the increase was only half a year. According to Goldin and Katz, the most remarkable aspect of the U.S. labor market from 1970 on has been the rapid slowdown in accumulation of human capital relative to the steady growth in the previous century. These arguments are supported and extended by Acemoglu and Autor (2012) in their review of the Goldin and Katz book (see in particular Figures 12 and 13). The following tables summarizes OECD results on differences in educational results between the U.S., OECD countries, and EU21, which consists of European countries that are in OECD.[18]

An immediate observation from Table 14 is that percentage attainments in upper secondary and tertiary education are about the same for young (25-34) and old (55-64) in the U.S. Entry of new workers into the labor market to replace retiring workers will then have little effect on overall educational averages. In contrast, younger cohorts have substantially higher attainment levels in the OECD and EU21 groups, so that their averages will continue to rise. As a consequence, the slowdown in human capital accumulation in the U.S. described by Goldin and Katz can be expected to continue. A related observation is that enrollment rates for individuals 20 to 29 have experienced greater growth for the OECD and EU21 groups than for the U.S., while growth for individuals 15 to 19 is similar. Graduation rates from upper secondary levels is lower for the U.S. The EU21 group also shows a greater increase in graduation rates from tertiary university education than the U.S. These specific comparisons support the Goldin and Katz argument that the growth rate of human capital in the U.S. has slowed, and point to significant differences between the U.S. and countries in the OECD and EU21 groups.

[18] In these tables, OECD refers to its 34 member countries, including the U.S., and EU21 refers to the 21 OECD countries that are also members of the European Union and for which data are available (see OECD, 2011d, p. 8 for specific lists of countries). Primary education (ISCED classification 1) lasts 6 years after entry at ages between 5 and 7, and lower secondary education (ISCED 2) follows primary education and lasts about 3 years. Upper secondary education (ISCED 3) corresponds to high school in the U.S. Post-secondary non-tertiary education (ISCED 4) covers programs that prepare students for tertiary education or entry into the workforce. Tertiary education (ISCED 5) corresponds to college and is divided into two subcategories, university-level education (ISCED 5A) and vocationally oriented education (ISCED 5B).

Table 14: OECD Educational Enrollment and Attainment Statistics

Criterion	Year	OECD (2011c) Table	U.S.	OECD	EU21
Percentage attaining upper secondary, 25-34	2009	A1.2a	88	81	83
Percentage attaining upper secondary, 55-64	2009	A1.2a	89	61	63
Percentage attaining tertiary, 25-34	2009	A1.3a	41	37	34
Percentage attaining tertiary, 55-64	2009	A1.3a	41	22	20
Enrollment Rates, 15-19, Full and Part Time	1995	C1.2	72	73	77
Enrollment Rates, 15-19, Full and Part Time	2009	C1.2	81	82	86
Enrollment Rates, 20-29, Full and Part Time	1995	C1.2	19	18	19
Enrollment Rates, 20-29, Full and Part Time	2009	C1.2	24	26	27
Upper Secondary Graduation Rate as % of Population	2009	A2.1	76	82	85
Entry Rates to Tertiary University Education	1995	C2.2	N.A.	37	35
Entry Rates to Tertiary University Education	2009	C2.2	70	59	58
Graduation Rates, Tertiary University Education	1995	A3.2	33	N.A.	18
Graduation Rates, Tertiary University Education	2009	A3.2	37	N.A.	39
Graduation Rates, Tertiary Vocational Education	1995	A3.2	9	N.A.	9
Graduation Rates, Tertiary Vocational Education	2009	A3.2	11	N.A.	8

Sources: OECD (2011c, 2011d)

The increase in the college premium, combined with the slowdown in the accumulation of human capital, raises an important issue: why did individuals in the United States fail to respond to higher college and high school premiums by greatly increasing their human capital investments? The following table presents OECD data that are relevant to a resolution of this paradox.

Table 15: OECD Educational Expenditure, Cost and Earnings Statistics

Criterion	Year	OECD (2011c) Table	U.S.	OECD
Relative Earnings Below Upper Secondary, 25-64	2009	A8.1	64/100	77/100
Relative Earnings for All Tertiary, 25-64	2009	A8.1	179/100	153/100
Private Direct Costs of Tertiary Education, Men and Women	2007	A9.3	$69,907	$10,746
Private Foregone Earnings of Tertiary Education, Men	2007	A9.3	$39,313	$40,479
Private Foregone Earnings of Tertiary Education, Women	2007	A9.3	$40,273	$38,759
Public Direct Costs of Tertiary Education, Men and Women	2007	A9.4	$32,281	$24,711

Sources: OECD (2011c, 2011d)

In this table, the relative earnings comparisons are calculated relative to earnings for post-secondary non-tertiary education (ISCED 4). They show that the educational differentials in 2009 were greater in the U.S. than in the OECD group of countries (exclusion of the U.S. from this group would not reverse the comparison). The net present value of private direct costs of tertiary (university) education in the U.S. ($69,907) were substantially higher than the level in OECD countries ($10,746), while the net present value of private foregone earnings were essentially the same. Ronald G. Ehrenberg (2012) and Robert B. Archibald and David H. Feldman (2011) have recently analyzed reasons for the increasing costs of U.S. higher education. The greater costs provide an immediate explanation for increasing educational differentials. Following Human Capital Theory, the initial effects of higher costs of university education will be a decline in numbers of individuals choosing university education at the previous low level of earnings for university graduates. As the number of university graduates declines, the marginal product and earnings of university graduates increase until the higher earnings compensate for the greater costs of the university education. At the end of the adjustment process, the educational differentials for university graduates will be greater but the numbers choosing university education will be smaller.

Other explanations are possible and may contribute to the result. Goldin and Katz suggest that graduation rates have declined because U.S. schools do not provide high quality education to less advantaged students (see also comments by Acemoglu and Autor, 2012, p. 31, in their review of Goldin and Katz's book). Carneiro and Heckman argue that there are widening gaps in college attendance by income and ethnic group (2003, pp. 84-85), so that many groups are not responding to increasing wage and educational differentials. They emphasize noncognitive skills in explaining why some individuals would not invest

in human capital in response to higher wage differentials. A second explanation is that higher education has increased in cost so much that credit constraints are now binding, restricting decisions to invest in human capital (Lance Lochner and Alexander Monge-Naranjo, 2011). A third explanation is that with greater wage dispersion within educational categories, students expect compensation for greater risk (Juerg Schweri, Joop Hartog and Stefan C. Solter, 2011). Also, although the average return to college in the United States has increased, the return that particular individuals could achieve by attending college has not necessarily gone up. Carneiro and Heckman suggest that improving noncognitive skills at early ages would increase college attendance more than reductions in tuition.

3.4 Consequences of Long Run Aggregate Qualitative Mismatches

3.4.1 Job Polarization

Job polarization describes a major consequence of qualitative mismatches for the labor market and provides a means of distinguishing between different causes of changes in jobs. Dividing jobs into three categories of low skilled, middle and high skilled, job polarization arises from a decline in the middle category relative to the upper and lower categories. Although job polarization was once attributed to the operation of a capitalist system in reducing the discretion and authority of the middle category of workers, current explanations attribute the phenomenon to technological change, globalization, or institutions.

Maarten Goos, Alan Manning and Anna Salomons (2011) undertake an empirical examination of job polarization in 16 European countries and compare alternative causes of that polarization. Pooling data for the 16 countries between 1993 and 2006, the authors find that the lowest-paid and highest-paid categories of occupations have grown relative to the middle category (2011, Table 1 and Figures 1 and 2), documenting the magnitude of job polarization. They construct a model of the demands for occupations within industries using a production function in which tasks provided by occupations are combined with other factors to yield output, similar to the use of tasks in Autor, Levy and Murnane (2003), Autor and Dorn (2010) and Acemoglu and Autor (2011). They use O*NET data on occupational tasks to derive three measures of tasks for each occupation: abstract, routine or service. They also summarize this information in a single-dimensional Routine Task Index (RTI). To compare the effect of these variables with Skill Biased Technological Change, they also calculate the mean educational attainment by occupation. To construct an index of offshorability for each occupation, Goos, Manning and Salomons process information from the European Restructuring Monitor of the European Monitoring Centre on Change. Corresponding information on wages is taken from the European Community Household Panel, the European Union Statistics on Income and Living Conditions and, for the United Kingdom, the Labor Force Survey.

The data are used to estimate changes in demands for occupations assuming

industry outputs have not changed. With the three task measures and offshorability included, the estimates indicate that employment growth was .81 percent higher per year for occupations one standard deviation higher in abstract tasks, and was .75 percent lower for occupations one standard deviation higher in routine tasks (Table 6A, column 10; the table includes other combinations of variables). In the same estimation, employment growth was higher when the service task measure was greater and offshorability lower, but these relations were not significant. In Table 6B, the authors consider whether technological change affects jobs through its effects on demands for skills or through its effects on demands for tasks. The difference is that in SBTC, the change in demand for an occupation depends only on the skill (or educational) requirements of the occupation. In contrast, in the routinization hypothesis of Autor, Levy and Murnane, the relevant characteristic of an occupation is the extent of routine tasks rather than the skill level, and routine tasks and skill levels vary differently from occupation to occupation (Goos and Manning, 2007). If the SBTC hypothesis were valid, information about the task measures would provide no additional information about occupational demands. Column 2 of their Table 6B shows that the measures of abstract and routine tasks remain significant when educational level of an occupation and offshorability are included, indicating that the routinization (or task-biased technological change) theory provides a significant explanation for changes in demands for occupations. The authors also conclude that employment in some occupations has been offshored to a limited extent.

Goos, Manning and Salomons additionally consider product demand effects, which would dampen the effects of technological change. To explain this phenomenon, they describe an example provided by Paul Krugman (1999), in which the production of a hamburger requires one bun and one meat patty. If the labor needed to produce a bun declines, the direct effect (not accounting for any change in hamburger production) would be a decline in employment of bun workers with no change in number of patty workers. However, the price of a hamburger would decline, increasing employment of patty workers and reducing the loss of employment of bun workers. The authors conclude that these price effects are non-trivial and must be included in the analysis.

While Goos, Manning and Salomons consider task-biased technological change, Guy Michaels, Ashwini Natraj and John Van Reenen (2010) investigate whether job polarization arises more specifically from information and communications technologies (ICT). Their strategy is to estimate the relation between the rate of growth of ICT and the rates of growth of wage bill shares for high education and middle education workers using industry data for eleven countries (Austria, Denmark Finland, France, Germany, Italy, Japan, the Netherlands, Spain, the United Kingdom, and the United States). The major source of data is EUKLEMS, which provides an internationally-comparable industry-level panel data set for countries using each country's census bureau over the period 1980 to 2004. The authors compare changes in wage bills to changes in ICT investment over the 24 year period in Table 3. With both ICT and non-ICT investment included along with country fixed effects (column 3), the change in ICT invest-

ment significantly raised the wage bill for high-skilled workers and lowered the wage bill for middle-skilled workers. The coefficient for non-ICT capital is not significant for the wage bills, suggesting that a narrow version of capital-skill complementarity (with no distinction between ICT and non-ICT capital) is inconsistent with the results. The results remain valid when the data are limited to industries with tradable goods. The ICT data does not provide a significant explanation for changes in the low-skilled wage bill share. The authors also check whether trade could cause the wage bill changes. While trade is significant in some specifications, the coefficient is insignificant when ICT investment and initial research and development intensity are included.

David Autor and David Dorn (2010) investigate the consequences of job polarization for low skilled workers based on cross-sectional evidence from local labor markets. They consider an economy where there are basically three groups of labor, highly skilled workers engaged in abstract tasks producing goods, and low skilled workers that are either engaged in routine tasks producing goods or low skilled labor producing services. As computers fall in price, they are substituted for the routine tasks performed by low skilled workers, leading those workers to shift to services, generating employment polarization. At the same time, if consumption preferences are such that goods and services are weakly complementary (meaning that consumers prefer combinations of goods and services to all of one or the other), increased incomes will generate higher wages for service workers, yielding wage polarization. Autor and Dorn develop a model showing how mobile high skill workers would sort themselves among localities, equalizing their real wages. The authors use definitions of local labor markets determined by commuting patterns (Charles Tolbert and Molly Sizer, 1996). A routine employment share is determined for each Commuting Zone using routine-task intensities for occupations from Autor, Levy and Murnane (2003). The authors show that Commuting Zones that specialized in routine-intensive work showed greater employment polarization (Figure 3A) as predicted by the model. Figure 3B shows that Commuting Zones with more routine-intensive work also had more wage polarization. Using a measure of computer penetration for each Commuting Zone, the authors further show that higher routine-intensive work is associated with greater adoption of computer technology (Table 2) and greater growth of service employment (Table 3). Autor and Dorn show that the impact of initial routine-intensive work remains after inclusion of alternative explanatory variables including changes in ratios of college and immigrant workers to the non-college population, manufacturing employment, the unemployment rate, female employment, and workers over 65 (Table 4) or offshorability (Table 5). The authors also provide more detailed evidence on the effects of initial routine-intensive work on wages for six groups of occupations (Table 6).

3.4.2 Inequality

The study of long run qualitative mismatches has benefited from the literature that addresses inequality, including job polarization.[19] This literature includes capital-skill complementarity, skill biased technological change, computerization, globalization, and organization of work, which are regarded as shifting the demand curve for skilled workers to the right in Figure 7. It also includes the slowdown in accumulation of human capital relative to steadily increasing demands, which would shift the supply curve in Figure 7 more slowly to the right. This literature, taken as a whole, establishes the reasons why educational differentials have increased, particularly in the U.S. The authors of the studies that explain increasing inequality through increasing education and skill differentials take it for granted that increasing differentials and increasing inequality are synonymous and do not establish the link between the two separate phenomena. Examining this link will demonstrate the relevance of qualitative mismatches to inequality.

The most direct relationship between educational differentials and inequality arises from Aitchison and Brown's analysis of the lognormal distribution (1957; see also Sattinger, 2008). Suppose the labor force can be decomposed into sectors determined by educational levels. Suppose the distribution of earnings for each educational level is lognormal with variance σ^2, the same for each sector. Suppose the arithmetic mean earnings in sectors are themselves lognormally distributed with parameters μ_0 and σ_0. The distribution of log earnings will then also be lognormal with logarithmic mean $\mu_0 - \sigma^2/2$ and variance $\sigma_0^2 + \sigma^2$. Harold Lydall (1968, p. 104) applied this decomposition to 1959 U.S. occupational data and found that differences among occupations contributed little to overall inequality as measured by the variance of logarithms. The reason is that σ_0^2 is small relative to σ^2, so that a change in σ_0 from increasing occupational differentials will have little effect on overall inequality. The difference in earnings by educational level is also small relative to the differences within education levels. Therefore an increase in the educational differentials will have a minor effect on inequality instead of being equivalent to the increase in inequality. Selection among sectors as in the Roy model does not change this result since the upper and lower tails of the income distribution remain substantially the same after selection. As a result of the weak connection between educational differentials and inequality, the authors who have attempted to explain increasing inequality through higher skill differentials have not accomplished their stated goals, although their work nonetheless contributes to our understanding of economic differences.

Acemoglu and Autor (2012), in their review of Goldin and Katz's book, do not challenge the connection between educational differentials and inequality,

[19] The vast literature on income distribution is surveyed in Sattinger (2001). Standard references include J. Bound and G. Johnson (1992), D. Card and J. DiNardo (2002), James Heckman, Lance Lochner and Christopher Taber, 1998), C. Juhn, K. Murphy and B. Pierce (1993), L. Katz and D. Autor (1999), Thomas Lemieux (2006) and Frank Levy and Richard Murnane (1992).

but they argue that assignment models provide a better explanation for changes in income inequality by recognizing multidimensional attributes of labor and the relevance of tasks. They describe the supply and demand model used by Goldin and Katz and the literature on capital-skill complementarity, skill biased technological change and computerization, as the canonical model. They suggest that an assignment model would add to the explanatory power of the canonical model by more accurately generating wage inequality, falling real wages for less skilled workers, and polarization of occupations and earnings growth. The model they develop, while an advance in many respects, is deterministic: it steps back from the contributions of job search and does not generate mismatches.

Goldin and Katz (as well as their reviewers, Acemoglu and Autor, 2012) adopt Tinbergen's characterization of the evolution of inequality without considering the basis for his work. The reference to a race between technological development and education apparently appears first in a paper on the extent of substitutability between graduates (college, third-level, or tertiary) and other labor (Tinbergen, 1974). In early educational planning there were assumed to be rigid requirements for numbers of workers at different educational levels to perform particular occupations. Substitution makes it possible to go beyond this limit and incorporate more educated workers into the labor force. Tinbergen works with a Cobb-Douglas production function with exponent α_3 for the quantity of graduate labor, given by L_3. Then the income per worker for graduate labor will be proportional to α_3/L_3, and their share of income will be α_3. In this simple model, technological change takes the form of an increase in α_3, similar to technological change in Manacorda and Petrongolo (1999). With three types of labor (homogeneous within types), inequality is directly linked to the ratio α_3/L_3. The race between technological change and education then follows naturally from the relative changes in α_3 and L_3. The link is not metaphorical but is instead based on a rigorous model.

Tinbergen's later discussion of the race has been neglected (Tinbergen, 1975, Chapter 6; see the review by Richard Haveman, 1977). There, Tinbergen argues that economies would be able to absorb increasing numbers of highly educated workers without experiencing overeducation imbalances as a result of the substitutability. He further observes that the race between technological development and education may be lost in the U.S. (1975, p. 103), the same trend that has been documented by Goldin and Katz.

To explain the evolution of inequality, it is necessary to consider the dispersion of earnings within educational levels as well as educational differentials. Fabian Slonimczyk (2012) shows how qualitative mismatches are related to changes in inequality through their effects on dispersion of earnings for particular groups of workers. The wage premia and penalties from mismatch contribute to the dispersion of wages within a skill or educational level and therefore generate greater inequality. Slonimczyk uses the Shapley value decomposition developed by Shorrocks to decompose the changes in inequality into contributing factors. He finds that overqualification and underqualification (or surplus and deficit qualification) in the U.S. in 2002 account for 4.3 percent and 4.6 percent of the variance of log earnings for males and females, or about fifteen

percent of total explained variance. Changes in overqualification contributed 6.5 percent for males and 8.1 percent for females of the increases in variance in log earnings over the period 1973 to 2002. Using the Gini coefficient, the contributions were greater, 20 and 48 percent, respectively. Slonimczyk's results show how qualitative mismatches can be rigorously related to inequality.

3.4.3 Restricted Firm Expansion and Economic Growth

A potentially large consequence of a long run aggregate qualitative mismatch, with supplies of highly skilled workers falling behind demands for them, is that the mismatch may constrain the growth of an economy. In particular, firms in advanced, high-technology sectors of the economy may be unable to expand because of an inability to hire adequate numbers of educated and skilled workers. Using surveys of information technology, electronic engineering and mechanical engineering industries in Northern Ireland, Jessica Bennett and Seamus McGuinness (2009) investigate whether unfilled and hard-to-fill vacancies arising from skill shortages limit the productivity of firms. They find that high productivity firms are much more likely to experience these skill shortages, and the vacancy constraints reduced productivity by 65 percent to 75 percent.

As noted by Hartog (2000) and Leuven and Oosterbeek (2011), the wage regressions that include overeducation and undereducation cannot be used to determine the investment returns to education since the causal relation between education variables and wages has not been determined. In a separate literature, economists studying the determinants of economic growth have estimated the contributions of education and cognitive skills. Eric Hanushek and Ludger Woessmann (2010) construct three scenarios to forecast the contributions of higher educational achievement on economic growth through 2090, presented in Table 15. The scenarios are expressed in terms of alternative changes in countries on the PISA (Programme for International Student Assessment) tests of cognitive skills (OECD, 2007b). The third scenario is determined by the European Union's benchmark goal for low achievers to reduce their percentage below 15 percent by 2020 (Commission of the European Communities, 2009).

Table 16: Present Values of Educational Reforms

	Description	Present Value of Change for EU Countries Through 2090
Scenario I	Raise performance on PISA tests by 25 points, or 1/4 standard deviation	€32 Trillion
Scenario II	Bring each country up to PISA level for Finland	€87 Trillion
Scenario III	Reduce percentage of low achievers to less than 15 percent by 2020 (EU Benchmark)	€21 Trillion

Source: Hanushek and Woessmann, 2010

These figures are enormous. Of course, a major problem is that estimates of the contributions of cognitive skills may include returns to other changes in economies that occurred at the same time (see Hanushek and Woessmann, 2009, for a discussion of causality concerns). In particular, the estimates disregard the importance of noncognitive skills emphasized by Pedro Carneiro and James Heckman (2003, p. 137). Also, if Daron Acemoglu (2002) is correct regarding endogenous technological change, it would be difficult to disentangle the effects of educational variables from simultaneous technological changes taking place in economies.

The qualitative mismatch literature provides an additional perspective on contributions of educational changes to economic growth. The Hanushek and Woessmann estimates of educational achievement effects on growth are constant and independent of the states of the economies. In contrast, in the qualitative mismatch literature, an increase in supplies of individuals with higher educational and skill levels will generate increases in overeducation for a given level of job requirements, with potentially lower effects on growth. Lower levels of educational achievements could serve as a limitation on growth rates, so that raising educational achievements would have greater effects on growth. Kitae Sohn (2010) has shown that the returns to cognitive skills depend on required education, so that returns to cognitive skills could not be projected to conditions without parallel growth in required educational levels. As a consequence, the qualitative mismatch perspective suggests that the effects of greater levels of educational achievement will be nonlinear and depend on demand factors. Whether such nonlinearities could be detected in the economic growth data is unclear. A straight-forward approach, at least conceptually, would be to adapt the Duncan-Hoffman approach to the endogeneous growth estimations. Instead of a measure of homogeneous human capital, measures of overeducation, required education and undereducation would be used based on projected de-

mands for human capital. Absence of nonlinear effects of human capital could be determined by testing the null hypothesis that the effects of the three categories of education were equal. Determination of these three categories may be complicated by the result that schooling may not have a significant effect on growth rates if measures of cognitive skills are included (Hanushek and Woessmann, 2012, p. 80).

3.5 Policies

The major policy to reduce future long run qualitative mismatches is to anticipate them by preparing the labor force for changes in jobs. A first step is to determine future supplies and demands for labor, followed by a description of what future work will be like. Finally, policies need to be developed to prepare individuals for future work through formal education, on-the-job training, and life-long learning.

3.5.1 Future Supplies and Demands

CEDEFOP (2010a) has undertaken a major project to provide detailed forecasts to 2020 of supplies and demands for labor by sector, occupation, and qualification for each of 27 European countries using common methods and comparable data sources. The components of the forecasts are divided into modules. Module 1 is based on the E3M3 (Energy-environment-economy model of Europe) multisector econometric macroeconomic model that generates both supplies and demands for labor. On the demand side, modules then generate employment levels, expansion and replacement levels by occupation and qualification as well as job openings. On the supply side, modules generate the stocks of people by economic status and ISCED (International Standard Classification of Education), flows and graduates and labor force by ISCED category. Imbalances between supplies and demands by ISCED level are reconciled by the final module, which among other adjustments reallocates supplies to the jobs calculated on the demand side. Different scenarios (p. 36) are considered based on recovery from the recent economic crisis, growth in Gross Domestic Product, and alternative labor supply and demand growth rates. The forecasts provide detailed results for each country by occupation, sector and qualification level. The results reflect some degree of job polarization, with substantial growth in high-skilled non-manual occupations, little growth in skilled non-manual occupations, decline in skilled manual occupations, and slight growth in elementary occupations (pp.68-70). In terms of qualifications, increased skill requirements are expected for all jobs.

For the United States, David Neumark, Hans P. Johnson and Marisol Cuellar Mejia (2011) forecast the levels of skill shortages through 2018 using U.S. Bureau of Labor Statistics occupational projections (see also CEDEFOP, 2010c). Usually, individuals that retire are replaced by young graduates that have more education, raising average educational levels. However, baby boomers (born between 1946 and 1964) have educational and skill levels that are almost

as high as graduates that are entering the labor force, so their retirement in the next few decades will not raise educational averages. Neumark et al conclude that these retirements are unlikely to cause skill shortages by the end of the decade, except possibly in some states with large and increasing immigrant populations. Nevertheless, skill shortages could occur as retirements continue beyond 2018.

The same subject has been examined in less quantitative detail in a workshop convened on "Research on Future Skill Demands," organized by the National Research Council of the National Academies, chaired by Richard Murnane, and summarized by Margaret Hilton (2008). The workshop reviewed different research methodologies and data sources that could be used to forecast future skill demands and supplies, and considered whether skill demands would be significantly different in the future, requiring public policy responses in preparing individuals for work. Papers prepared for the workshop are discussed at various points in this review, including Autor (2007), Handel (2007) and Elliott (2007).

Gerard van Vugt (2012) analyzes the consequences of technological change for overall employment. Just as manufacturing replaced artisan workers and automation replaced production workers, he concludes that technology will eventually replace the use of human skills, generating extensive unemployment along with rises in unemployment.

3.5.2 Future Jobs and Skill Needs

The following table indicates the range of results regarding future jobs and skill needs that have been generated by various studies. The conclusions extend beyond the brief citations listed here and are not contradictory since they may apply to different segments of the workforce.

Table 17: Statements of Future Jobs and Skill Needs

Source	Region, Country or Countries	Conclusions
Assessment and Teaching of 21st Century Skills, Univ. of Melbourne (2011, p. 15)	All countries, with particular consideration of Australia, Finland, Singapore and United Kingdom	Ten skills grouped into four categories: ways of thinking, ways of working, tools of working, living in the world
Autor, Levy and Murnane (2003)	United States	Non-routine jobs that would not be performed by computers
Autor and Dorn (2010)	United States	Non-routine low-skilled jobs and jobs requiring high skills
Blinder (2009)	United States	Jobs that require face-to-face interactions and that cannot be performed at a remote location without being severely degraded
Caroli and Van Reenen (2001)	United Kingdom, France	Workplaces with decentralized authority, flatter managerial hierarchy, increased multi-tasking
CEDEFOP, Skills Supply and Demand in Europe (2010a, p. 70)	EU-27	Continued strong growth in high qualification jobs, decline in low qualification jobs, small growth in medium qualification jobs; more specific results in tables
Elliott (2007)	All Countries	Jobs with Language or Reasoning O*NET ability levels ≥ 5 or Vision and Movement levels ≥ 4

Table 17: Statements of Future Jobs and Skill Needs, Continued

European Expert Network on Economics of Education (2008, p. 28)	Europe	More general skills providing interpersonal and environmental adaptability or flexibility
Goldin and Katz (2008, pp. 352-353)	United States	Provide students academically prepared for college (p. 347); highly analytical individuals who can think abstractly or can provide skilled in-person services
Holzer and Nightingale (2007)	United States	Greater education and skills, wide range of skills, education and training somewhat targeted to private-sector
Levy (2010)	OECD Countries	Foundational skills including numeracy and literacy, advanced problem-solving skills, and advanced communication skills
Lindbeck and Snower (1996, p. 320)	United States and United Kingdom	Workers with broad-based education, multi-tasking, customer-oriented teams, reduction in middle management
Murnane (2008, p. 84)	United States	Interpersonal skills including written communication skills, knowing how to work well with various people cultures, and knowing how to give and receive advice
National Research Council (2010)	United States	Adaptability, complex communication/social skills, nonroutine problem solving, self-management/self-development, systems thinking
OECD (2011a, p. 29)	OECD Countries	Apart from basic literacy and numeracy skills, little evidence of what other skills are required for better outcomes or more fluid labor market
SEO Economic Research (2010, p. 49)	Europe	Aging will increase employment in health and leisure sectors, while manufacturing declines
Shapiro, Lauritzen and Irving (2011)	U.S. and Europe	Growth in low value-added manual service jobs and increased demand for sophisticated skills required to implement and manage technology
Wasmer et al (2007, p. 118)	Europe	Increase tertiary education

3.5.3 Changes in Educational, Training, and Vocational Systems

The U.S. has pursued educational policies that are different from other countries. The following table describes financial aspects of those differences.

Table 18: OECD Educational Expenditures

Criterion	Year	OECD (2011c) Table	U.S.	OECD	EU21
Annual Expenditure per Student, Pre-Primary	2008	B1.1a	$10,070	$6,210	$6,397
Annual Expenditure per Student, Primary	2008	B1.1a	$9,982	$7,153	$7,257
Annual Expenditure per Student, Secondary	2008	B1.1a	$12,097	$8,972	$9,116
Annual Expenditure per Student, Tertiary	2008	B1.1a	$29,910	$13,717	$8,831
Annual Expenditure per Student, All, Primary to Tertiary	2008	B1.1a	$14,923	$8,831	$8,702
Index of Real Spending Per Student (Base Year 2000), Below Tertiary	1995	B1.5	80	85	88
Index of Real Spending Per Student (Base Year 2000), Below Tertiary	2008	B1.5	125	129	129
Index of Real Spending Per Student (Base Year 2000), Tertiary	1995	B1.5	77	98	102
Index of Real Spending Per Student (Base Year 2000), Tertiary	2008	B1.5	98	114	119
Percent of GDP at All levels	2008	B2.1	7.2	5.9	5.5
Percent of Expenditures from Private Sources	2000	B3.1	32.7	13.7	7.9
Percent of Expenditures from Private Sources	2008	B3.1	29	16.5	10.9

Sources: OECD (2011c, 2011d)

The table documents greater levels of U.S. expenditure per student at all levels compared to the OECD and EU21 groups. The differences are particularly great for tertiary education, as noted previously in Table 13. Between 1995 and 2008, the U.S. indexes of real spending per student at the tertiary level and below increased more than for the OECD and EU21 groups. Along with higher costs of education, the percent of GDP at all levels going to education was greater in the U.S. than in the OECD and EU21 groups. The slowdown in human capital accumulation in the U.S. described by Goldin and Katz contrast with the statistics from Table 16 showing higher and increasing expenditures on human

capital in the U.S. The statistics from Tables 13 and 16 point to a significant difference between the U.S. and other countries: costs of education are higher in the U.S., so that policy cannot simply recommend greater human capital investments. Another difference, previously noted by Wasmer et al (2007), is that the percentage of expenditure from private sources is much higher in the U.S. than in the OECD and EU21 groups.

European Union policies for education and training are stated in the 2009 Strategic Framework for European Cooperation in education and training (referred to as ET 2020). A recent review describes progress towards these goals (European Commission, 2012). The first area, investment and reforms in education and training, concerns public budgets and investments. The second area, early school leaving, would reduce the share of 18 to 24 year olds leaving education or training prematurely to less than ten percent by 2020. For the third area, tertiary or equivalent education attainment, the goal is to have 40 percent of 30 to 34 year olds with a degree at this level by 2020. For the fourth area, lifelong learning strategies, the goal is to have 15 percent of adults aged 25 to 64 participating in education and training, compared to 9.1 percent in 2010. Learning mobility, the fifth area, would extend labor mobility to graduates of vocational education and training programs by increasing the recognition of qualifications through the European Qualifications Framework, the European Credit System for VET, the European Credit Transfer and Accumulation System, and Europass. The sixth area, new skills and jobs, monitors progress in adapting education and training to long run changes in jobs generated by the phenomena discussed in this section.

Robert Lerman (2008) has reviewed U.S. education and training policies in comparison with European policies and recommends a number of changes. The U.S. lacks a well-structured approach to skills development compared to Germany and Japan, and has emphasized academic skills to prepare individuals for college rather than career and technical education. At the high school level, Lerman emphasizes the importance of recognizing the diversity of student interests, abilities, career aspirations, and career outlets (2008, p. 61). Students should be able to combine school-based instruction with work-based learning that leads to occupational certification and entry into post-program training. For adults, Lerman argues that apprenticeships are a form of work-based learning that provides long-term training to potential workers while requiring little or no foregone earnings for participants. However, federal funding for apprenticeships has instead been at extremely low levels. Lerman suggests that a change in accounting practices to count skill development as investment would improve the ability to measure and observe returns to firm investments in training.[20]

[20] Statements of appropriate changes in educational and vocational systems have been issued by the Asian Development Bank (2008), the International Labour Organization (2008), the Leitch Review of Skills (2006), and the Scottish Government (2007), among others. Heckman and Dimitriy Masterov (2007) emphasize positive outcomes from developmental child care before elementary school, particularly in the area of noncognitive skills.

4 Conclusions

A major intention of this review is to organize different aspects of qualitative mismatches to provide an outline of the subject, if not a complete picture. Many issues in qualitative mismatches can be divided between short run and long run analysis. Some elements of the subject have been the focus of substantial research, while others need further study.

Better measurement and observation of qualitative mismatches will greatly advance the subject.[21] As a result of the need to provide job counseling, countries have developed different systems of job descriptions such as the Dictionary of Occupational Titles in the U.S. However, little statistical evidence is available about firm recruitment practices to compare with worker job search procedures. What do firms observe about workers in the hiring process? What is the basis of an employer's decision whether to hire a particular worker? Panel surveys have provided a method of examining the relations between various forms of qualitative mismatches and other conditions of labor such as wages, job satisfaction, skill obsolescence, career mobility, and on-the-job search. Results have not always been consistent because the questions posed in surveys are not the same and respondents to a given survey can have different interpretations of the same question. In terms of descriptions of workers, data using objective assessments of worker skills and competences based on a standardized system would greatly facilitate comparable research. There is substantial recognition of the problem of comparable data in recommendations for questions in surveys and a standardized system of competences.

In papers that analyze the theoretical foundations of qualitative mismatches, assignment models are generally (but not universally) cited as the best explanation. Human capital models explain the relation between human capital and wages but job characteristics do not enter the fundamental analysis. Job competition models (Lester Thurow, 1975), in which job characteristics determine the wage, regard job qualifications as provided on the job and do not provide a basis for qualitative mismatches. Assignment models, by involving both worker and job characteristics, allow for wage consequences of qualitative mismatches. Combined with search and recruitment as mechanisms that assign workers to jobs, assignment models can generate qualitative mismatches with wage consequences corresponding to what is observed in the literature. However, assignment models have not been developed to provide a formulaic relationship between wages and worker and job characteristics when qualitative mismatches arise, or the combinations of worker characteristics that may be observed at a particular job type. As a result, the extensive literature on wage effects of overeducation lacks a theoretical foundation that would allow causal interpretation of the results, a shortcoming that is noted in reviews. Among other explanations, this survey

[21] Research priorities identified by CEDEFOP (2009) include improving measurement of skills and skill mismatch; examining the persistence of skill mismatch and its impacts; improving understanding of skill mismatch processes, its dynamics and the consequences of skill mismatch; focusing on skill mismatch for vulnerable groups on the labor market, and improving data availability and use.

shows that an assignment model with search and Nash bargaining can generate the pattern of wage differences observed in qualitative mismatch regressions.

The literature has identified particular groups for which qualitative mismatches pose significant problems. These include youth in their transition from education to stable employment, immigrants with skills and competences that are not known to prospective employers, unemployed workers for whom extended time out of work reduces their ability to find well-matched jobs, and aging workers who need to maintain skills to prevent skills obsolescence. These groups will continue to be the focus of empirical research and policy analysis.

In response to the 2008 financial crisis, economists have attempted to determine whether the Beveridge Curve generated in the search and matching literature has shifted, leading to higher levels of unemployment for given levels of vacancies. An answer has been sought in variations in unemployment to vacancy ratios among sectors of the economy. Instead, the large loss of jobs has affected the relation between job requirements and the qualifications of workers, causing changes in the type and number of worker-job matches in the economy. Some steps have been taken towards incorporating characteristics of workers and jobs into the matching function that is the basis for the search and matching Beveridge Curve, and this would appear to be a more promising direction for analysis.

The study of long run qualitative mismatches has benefited from the extensive research on the causes of increasing inequality, generally associated in the literature with increasing educational and skill premia. The sources of increases in inequality have long been characterized by Tinbergen's race between technology and education. As a consequence, economists and others have sought to explain increasing inequality in the factors that would shift the demands for more highly skilled workers. Answers have been found in skill biased technological change, computerization, organizational change and globalization. However, it appears that the explanation for increasing educational differentials lies more in the slowdown of investments in education as documented by Goldin and Katz, at least in the U.S. Sources of increases in demands for highly skilled workers, reduction in growth of human capital, and increasing educational and skill premia are very well documented. Less studied are the reasons why higher skill premia have not generated a supply response.

On the whole, qualitative mismatches present a combination of extensively observed empirical phenomena, important policy consequences, and incomplete theoretical foundation.

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