Skill Demands and Mismatch in U.S. Manufacturing: Evidence and Implications

Andrew Weaver*

Paul Osterman**

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Abstract. Elevated unemployment rates during and after the recession of 2007-2009 have revived debates over the degree of structural mismatch in the U.S. economy. One of the most frequent claims is that workers lack the skills that employers demand. Unfortunately, the existing literature analyzes mismatch at a high level of aggregation with abstract indices and noisy proxies that obscure the underlying mechanisms as well as the degree to which mismatch occurs within industries. We address these issues by presenting and analyzing results from a survey of U.S. manufacturing establishments. Our survey is the first, to our knowledge, to directly measure concrete employer skill demands and hiring experiences in a nationally representative survey at the industry level. We find that demand for higher level skills is generally modest, and that three quarters of manufacturing establishments do not show signs of hiring difficulties. Among the remainder, demands for higher level math and reading skills are significant predictors of long-term vacancies, but the relationship is not a mechanical one. Some establishment types with significantly higher skill demands—such as high-tech plants—do not have significantly greater signs of hiring problems. We interpret this finding to indicate that other factors mediate the relationship between skill demands and hiring outcomes, and that simple stories about inadequate workforce skills are misleading. The results imply that firm strategy and a range of institutional policies that go beyond calls for workers to increase educational attainment may be relevant to improving hiring outcomes.

*PhD candidate, MIT Sloan School of Management
**NTU Professor, MIT Sloan School of Management

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Matching skilled workers to appropriate jobs is one of the most critical processes in a modern economy. Firms depend on the timely supply of skills to grow and thrive, and workers depend on access to quality employment opportunities to achieve financial security and professional fulfillment. All parties have a vested stake in how the supply and demand for skills equilibrate in the labor market. Over the past few decades, recurring debates have taken place over whether mismatch exists in this process (Kalleberg 2007, Handel 2003, Berg 1970). Various researchers have posited that structural factors such as geographic immobility or shifting industry demands have driven a wedge between supply and demand, thus generating economic inefficiency and, in some cases, structural unemployment. One of the most frequent assertions is that workers lack the skills that employers demand, resulting in an economically damaging skill gap (Carnevale, Smith, and Strohl 2010; Manyika et al. 2011).

These arguments have intensified in the wake of the Great Recession of 2007-2009. While some analysts have concluded that cyclical factors were responsible for the subsequent high unemployment levels (Rothstein 2012, Lazear and Spletzer 2012), others continue to assert the importance of structural factors in generating mismatch (Mulligan 2009, 2011a, 2011b; Charles, Hurst, and Notowidigdo 2013). Although the balance of the evidence tends to point to the centrality of cyclical factors (Neumark and Valletta 2012), a number of researchers who acknowledge the importance of cyclicality nevertheless find non-trivial levels of structural mismatch (Sahin et al. 2012; Estevau and Tsounta 2011; Rothwell 2012; Canon, Chen, and Marifian 2013). One of the challenges in sorting through these claims is that the debates frequently take place at high levels of abstraction with imprecisely measured proxy variables.

Most prior research does not measure either the skills employers demand or the degree to which employers have difficulty in securing these skills (Kalleberg 2007; Handel 2010). Furthermore, much of the existing evidence on this topic takes place at the inter-industry level (Sahin et al. 2012; Canon, Chen, and Marifian 2013). While this approach is informative, it ignores mismatch that may occur within industries, and it obscures the mechanisms that underlie labor market frictions. In particular, mismatch indices typically cannot pinpoint the degree to which a shortfall in particular workforce skills is associated with signs of mismatch. Addressing this gap in the research is important because skill mismatches are a nearly constant source of public debate and carry substantial public policy implications.

We seek to add to knowledge about skill mismatch by examining employer-level data within a broad industry sector in order to gauge the incidence of the problem and to uncover which mechanisms are at work. Specifically, we explore mismatches related to worker skills ("skill gaps") by examining detailed evidence on employer skill demands and hiring experiences in the manufacturing sector. We pose the following questions: What are the skills that manufacturers demand for production workers? What happens when employers attempt to hire skilled production workers? Do they encounter problems, and, if so, what are the characteristics associated with these problems? To address these issues, we designed and administered a nationally representative survey of manufacturing establishments that, to our knowledge, provides data on skills and hiring that are unavailable from any other source.

Manufacturing provides a compelling setting for the examination of these issues for several reasons. First, industry advocates frequently assert that a large skill gap exists in manufacturing based on anecdotal evidence and opinion surveys (Deloitte 2011, Haas and Kleinfeld 2012). Second, the U.S. manufacturing sector is capital intensive and sensitive to

technological shocks. Given that one of the main arguments about the source of skill gaps points to technologically induced increases in skill demands, manufacturing—particularly various high-tech manufacturing subsectors—supplies an interesting test case for these theories. Finally, despite the sector's recent challenges, it remains of great interest in its own right as the generator of 12 percent of U.S. gross domestic product (GDP) as well the source of 70 percent of U.S. corporate research and development spending (Bureau of Economic Analysis 2013, Ezell and Atkinson 2011).

To preview our results, we find that three quarters of manufacturing establishments do not have persistent problems hiring the skilled production workers they demand. Consistent with this finding, the general pattern of skill demands in the manufacturing sector is one of widespread demand for basic skills but generally modest demands for extended or advanced skills. Among the roughly 15-25 percent of establishments that do show signs of prolonged hiring difficulties, higher-level demands for reading and math are important factors. Other skill demands, including those for soft skills and various high-performance work characteristics (such as initiative), are not related to signs of mismatch. Most intriguingly, some of the employers with the highest skill demands—high-tech establishments—actually have a significantly lower likelihood of experiencing hiring difficulties, indicating that there is no mechanical relationship between high skill demands and hiring problems. We interpret this latter result as showing that factors such as institutional climate and managerial strategy are potentially important in mediating hiring outcomes and that simple stories about inadequate workforce skills are misleading.

The structure of the paper is as follows. In the first section we discuss the debate over labor market mismatch and skill gaps. In the second section we outline our empirical strategy.

We then describe our survey methodology, followed by a presentation of data on the skills that manufacturers demand. Next, we explore the characteristics of establishments that have higher skill demands. We then examine evidence on the incidence of hiring difficulties as indicators of skill gaps. We subsequently analyze the characteristics that are associated with such difficulties. In the final section we conclude.

The Debate over Skill Gaps and Mismatch

The smooth functioning of the labor market depends on the equilibration of the supply and demand for skills, which in turn depends on matching workers to job openings. To the extent that mismatch or a gap exists between supply and demand, economic growth will suffer and workers with ill-matched skills will experience reduced economic opportunities or unemployment. Recessions, and the deteriorating labor market conditions that accompany them, tend to spark vigorous debate about how much of the observed increase in unemployment is due to temporary business cycle factors, and how much is due to more permanent structural characteristics of workers, firms, institutions, or geographic regions (Kalleberg 2007). Unlike mismatch due to cyclical causes, structural mismatch will, by definition, persist even as general economic conditions improve, thus making it an issue that must be dealt with through some combination of structural reforms, policy interventions, and behavioral changes among workers.

Recently, researchers have made a number of attempts to quantify the level of structural mismatch in the economy, often employing quite different approaches to the topic. Mulligan (2009) uses a Cobb-Douglas production function to decompose labor market changes into shifts in productivity and shifts in labor supply. He concludes that negative shifts in labor supply are behind the spiking unemployment in the Great Recession. In subsequent work, he asserts that

comparison of the incidence of government benefit programs with unemployment patterns implies that the labor market disincentives associated with government programs are to blame (Mulligan 2011a, 2011b).

A number of researchers have composed mismatch indices in order to measure whether imbalances exist that imply structural unemployment. These indices typically employ one of two broad methodologies. The first consists of calculating the ratio of unemployment to vacancies and interpreting the variation in this measure across industries as a sign of structural mismatch. This methodology is conceptually similar to a Beveridge-curve approach to mismatch. The second methodology consists of estimating industry demand for various skills, subtracting estimated regional supply of these skills, and labeling the difference a measure of mismatch.

Utilizing the first, Beveridge-style methodology, Sahin et al. (2012) find that labor market mismatch may be responsible for up to a third of the increase in unemployment from the Great Recession.[1] Canon, Chen, and Marifian (2013) calculate several alternative indices of this sort and conclude that mismatch could explain up to 51% of the unemployment increase. Estevau and Tsounta (2011) employ a version of the supply/demand index methodology to find that mismatch may account for 20 to 30 percent of the rise in unemployment. Other researchers using variations of this latter methodology also find a significant role for structural mismatch (Rothwell 2012; Carnevale, Smith, and Strohl 2012; Manyika et al. 2011).

If these conclusions are accurate, they imply that improvements in the overall economy will be insufficient to return America to pre-recession levels of unemployment in the absence of structural reforms. However, before sounding alarm bells, it is worth asking what these various measures of labor market mismatch have in fact taught us. Unfortunately, while some of these

[1] Sahin et al. (2012) emphasize the fact that they see cyclical factors as the primary force behind the spike in unemployment. Nevertheless, as noted above, their results imply a non-trivial role for structural factors.

research efforts are informative in that they point to issues worthy of more investigation, many of these attempts to measure labor market mismatch suffer from critical shortcomings. First, in order to be useful for policy purposes, it's necessary to identify the mechanisms that are driving labor market mismatch. Approaches such as Mulligan (2009) basically assume a mechanism and test for it by utilizing extremely specific functional forms that abstract away all complicating factors in the actual labor market. On the other hand, the mismatch indices are so general that it is often unclear what is being measured. They rely on highly aggregated data, are often conceptually vague, and lack the ability to identify underlying mechanisms. Industry unemployment/vacancy ratios could diverge due to a skills gap, geographic immobility, or a host of other factors. Even granting the relevance of general mismatch measures that obscure underlying causes, many of the indices are highly sensitive to cyclicality, thus calling into question the structural nature of the results (see Canon, Chen, and Marifian (2013) and Lazear and Spletzer (2012) for indications of cyclicality). Furthermore, as Rothstein (2012) notes, the Beveridge curve does not necessarily measure labor market tightness (and hence mismatch) because changes in firm strategy regarding recruitment intensity and wages can shift the curve independent of structural factors such as matching efficiency or the deficient skills of the workforce.

Supply/demand indices would seem to pinpoint the source of the mismatch as skill-related, but in fact they suffer from flaws of equal magnitude. Due to data limitations, none of these supply/demand indices directly measure either the demand for or the supply of skills. Rather, they utilize education as a proxy for skill. While understandable given constraints, this assumption is very problematic. On the demand side, changing educational composition does not necessarily measure skill demands. For example, if a college-educated individual takes a job at a

coffee shop, it would be misleading to conclude that skill demands for baristas have risen (Harrington and Sum 2010). On the supply side, educational proxies obscure variation in skill levels within educational categories. Such intra-category variation is arguably the largest and most important source of skill variation as most employers do not choose between filling a vacancy with a high school graduate versus a college-educated worker but rather choose between workers of different skill levels within a given educational category. Most troubling from a methodological point of view, these supply/demand indices use educational composition to measure both supply and demand. For example, researchers might estimate skill demands by calculating national educational attainment levels by industry, and skill supplies by calculating the local educational attainment of a metro region or a population of unemployed workers. Such methods are often equivalent to noting that education varies by region or within industries. This finding is often more of a truism than a research discovery.

In addition to these methodological concerns, there are some empirical findings that call the structural mismatch results into question. Rothstein (2012) investigates a battery of empirical measures to investigate structural claims. He demonstrates that unemployment levels among industries or groups that are often asserted to be the source of structural mismatch are not unusual once prior trends are taken into account. He also shows that aggregate, industry, and group-specific wages generally do not show the pattern of increases that would be consistent with structurally tight labor markets. Lazear and Spletzer (2012) add additional evidence that cyclical factors are central to explaining the rise in unemployment associated with the recession of 2007-2009. They demonstrate that although Beveridge-style indices based on the unemployment-vacancy ratio do show variation by industry, industry-specific changes in the ratio are proportional before and after the recession, yielding an overall level of industrial

mismatch in 2011 that is the same as the level that prevailed before the recession. Other researchers have similarly cast doubt on the importance of structural mismatch in explaining current economic conditions (Valletta and Kuang 2010; Dickens 2011; Daly, Hobijn, and Valletta 2011; Ghayad 2013).

Although the bulk of evidence supports the primacy of cyclical factors in explaining current elevated rates of unemployment across the entire economy (Neumark and Valletta 2012), there are several reasons why the issue of labor market mismatch remains unresolved. First, the methodologies of the debunking researchers, like those of the researchers who find structural mismatch, rely on highly aggregated data that cannot measure within-industry changes. This latter deficiency is important because much of the variation in skill demands and unemployment takes place at the intra-industry level. Speaking of labor demands, Modestino (2010, p.5) notes: "Most of the increased demand for college-educated workers in both New England and the nation comes from greater employment of college educated workers within industries and occupations." Similarly, with regard to the 2007-2009 recession, Lazear and Spletzer (2012, p.11) write: "Almost all of the action is in increasing within-industry unemployment rates, not in changes in the composition of different industries over time."

Another reason for further investigation of mismatch is that the counter-mismatch researchers discount structural explanations in part by conditioning post-recession outcomes on pre-recession trends (Rothstein 2012; Lazear and Spletzer 2012). Although this methodology is perfectly valid for determining whether structural mismatch can explain short-run changes, it lacks the ability to measure adverse labor market outcomes stemming from more long-term structural processes (such as skill-biased technical change). Employers on the ground could experience difficulties that are associated with growing trends that predated the 2007-2009

recession. In addition, even if labor market mismatch is not the primary cause, the possibility that mismatch could account for a quarter to a third of unemployment increases is worthy of attention (Sahin et al. 2012). Finally, although they should be treated with caution, there are innumerable ground-level reports of employers who cannot find the skilled workers they seek (Krouse 2013, Maltby and Needleman 2012, Whoriskey 2012, Woellert 2012). Applied researchers should always seek to explain divergence between micro phenomena and macro results.

One clear way to make progress in the debate over structural mismatch is to generate better data that 1) focus on within-industry variation, and 2) identify and appropriately measure the impact of a particular policy-relevant mechanism. This paper seeks to achieve these objectives by presenting original survey data on manufacturing skills and skill mismatch ("skill gaps"). We believe that building up detailed industry-level results is a necessary complement to the more abstract aggregate methodologies. To our knowledge, our survey is the first to directly measure both concrete skill demands and skill mismatch in an industry context.

We have chosen to focus on skill gaps—as opposed to other forms of mismatch—because the skills of the American workforce are a critical topic for economic policy, because there are frequent assertions that workers lack the skills to meet rising employer skill demands (Carnevale, Smith, and Strohl 2010; Manyika et al. 2011), and because the issue of skill mismatch is a constant source of public debate (Portman 2013, Emanuel 2011; Hemphill and Perry 2012, Friedman 2012, Baden 2011). Given this focus on skill mismatch, manufacturing offers a number of compelling features as a subject of investigation. First, arguments about skill mismatch are frequently applied to manufacturing. In a 2011 survey, the National Association of Manufacturers (NAM), in conjunction with Deloitte, concluded that "as many as 600,000 jobs are going unfilled" even in the face of an unemployment rate that at the time hovered around 9%

(Deloitte 2011). The same survey indicated that 67% of manufacturing respondents reported a "moderate to severe shortage of available, qualified workers." A full 74% reported that lack of skilled production workers had had a "significant negative impact on [their] company's ability to expand operations or improve productivity" (Deloitte 2011). The fact that such reports could emerge following a period where manufacturing employment declined by one third from 2000 to 2010—thus creating a reserve army of millions of trained manufacturing workers—begs the question of whether structural mismatch is to blame. Likewise, clear evidence that manufacturing wages have not risen for skilled production workers despite these claims of labor market tightness provides further impetus for investigation (Osterman and Weaver, forthcoming).

A second reason for examining manufacturing is that it is a generally capital intensive sector that is sensitive to technology shocks. Because some of the key theories about sources of mismatch-generating shifts in skill demands and supplies involve technology shocks (Autor, Levy, and Murnane 2003; Brynjolfsson and McAfee 2012), manufacturing is a logical place to look for these effects. On a related note, manufacturing is also a sector where technical skills—such as computer and math skills—are thought to be important. Given that these skills are often at the center of the skill debate, manufacturing provides fertile ground for inquiry.

Finally, despite its recent troubles, the manufacturing sector remains of interest due to its size and characteristics. It accounts for 12 percent of GDP, and it is responsible for about 70 percent of industry research and development spending (Bureau of Economic Analysis 2013, Ezell and Atkinson 2011). As a broad sector with substantial variation (high-tech vs. low-tech, domestic vs. export focus, etc.), it provides a productive test case for the exploration of skill demands and skill gaps.

Empirical Strategy

In order to gain traction on the question of whether skill gaps exist in the manufacturing sector, it is essential to directly measure skills and skill gaps. We seek to answer four questions via empirical analysis of our survey data: 1) what skills do manufacturers demand?, 2) what are the characteristics of establishments that demand higher skill levels?, 3) how widespread are extended hiring problems in the manufacturing sector?, and 4) for establishments with hiring difficulties, are these problems associated with higher skill demands or with the types of establishments that we have shown to have higher skill demands? As will be discussed below, we quantify hiring difficulties by measuring the number of core production worker vacancies that persist for three months or more.

We have two basic hypotheses. First, if skill gaps are a widespread problem in manufacturing, then extended core worker vacancies should be a widespread problem. As a benchmark definition of widespread, we can use the Deloitte/NAM survey finding that 74% of manufacturers report that a lack of skilled production workers had a significant negative impact on their operations (Deloitte 2011). Second, if skill gaps are a simple function of inadequate workforce skills, then extended vacancies should be positively and significantly related to both higher skill demands *and* to the types of establishments that have significantly higher skill demands. If extended vacancies are associated with skill demands in general but not with certain types of establishments that have significantly higher skill demands, this result would imply that skill gaps are not a simple or mechanical function of workforce skills and that other factors mediate the relationship. From a policy perspective, finding a mechanical relationship would imply that all policy interventions should simply focus on skill training and education. By contrast, a finding that the relationship is mediated by other factors would suggest that

considerations such as firm-level strategy or the institutional environment may be important in addressing the issue. The nature of these other factors would be a topic for further research.

Survey Methodology

As part of the Massachusetts Institute of Technology's Production in the Innovation Economy (PIE) project, we developed an original survey instrument that was mailed to 2,700 nationally representative manufacturing establishments with at least 10 employees beginning in October 2012.[2] The PIE survey focused on concrete skill questions, hiring and vacancy patterns, and establishment characteristics. The sample was randomly selected on a stratified basis from Dun & Bradstreet's database to reflect the frequency of different establishment sizes based on 2010 employment data from the Census Bureau's County Business Patterns survey. The sample was also trimmed to exclude industry codes for the baking, quick printing, and publishing industries.[3]

The survey administrators called each firm in the sample to identify the individual who would be the most appropriate respondent. The target respondents were either plant managers or human resources staff with knowledge of operations. As an incentive, and as compensation for response time, a $10 bill was included with each survey packet. Excluding the ineligible establishments, incorrect addresses, and the unusable surveys, the total response rate was 35.7 percent, yielding 903 completed surveys. Responses were submitted from October 2012 to January 2013.[4]

[2] For more information on the PIE project and its overall results, see Suzanne Berger, "Making in America," Cambridge, MA: MIT Press, 2013.
[3] We excluded these sectors because we feel that the industry dynamics associated with quick printers (such as FedEx/Kinkos), small bakeries, and newspaper/book publishers differs substantially from other manufacturing establishments.
[4] The results presented in this article include additional surveys submitted in January 2013 that were excluded from Osterman and Weaver (forthcoming).

To test the quality of the data we took two steps: a bias analysis using data available in the Dunn and Bradstreet universe on respondents and non-respondents to determine what response biases might exist, and, secondly, a comparison of patterns in our survey with those in the Census Bureau's Current Population Survey (CPS) in order to assess external validity.

We conducted the response bias analysis by using a linear probability model to regress an indicator for completing the survey on indicators for the various establishment size categories, indicators for geographic region, and indicators for two-digit SIC codes.[5] The results indicate that the largest size categories of establishments—those with more than 100 employees—were 12-20 percent less likely to respond.[6] We employ establishment size weights in our descriptive statistics to correct for these deviations. We also control for employment size in our regression specifications. Establishments in the South were eight percent less likely to respond than their counterparts in the Northeast. Other geographic differences were insignificant. Out of the 20 two-digit industry SIC codes, five were significantly more likely to respond than the base category of food products, with increased response probabilities in the 8-12 percent range. These sectors were: rubber and miscellaneous plastic; stone, clay, glass, and concrete; fabricated metal; industrial machinery and equipment; and electronic equipment except computers. Many of these are establishments in the size category—less than 100 employees—that was most likely to respond. Our use of establishment size weights and employment controls should mitigate this issue.

To test the external validity and data quality of our survey after the application of the relevant weights, we calculated a number of statistics on the profile of the production workers covered by the survey and compared these with comparable statistics on manufacturing

[5] We conducted this bias analysis with SIC rather than NAICS codes because only SIC codes were available for the nonrespondents in the sample.
[6] Results are available upon request from the authors.

production workers from the CPS. We should note that because the PIE Survey is an establishment survey and the CPS is a household survey, we expect some deviation between the two surveys.[7] The key question is whether the broad data patterns are similar. Table 1 contains the comparison data.

Table 1. Comparison of PIE and CPS Data

	PIE	CPS (2012)
Hourly wage	16.95	16.49*
Union	18.1%	13.7%*
Female	26.7%	26.6%
Age 30 or less	20.6%	21.3%
Age 31-40	27.5%	22%*
Age 41-55	35.8%	38.8%*
Age 56 plus	16.1%	17.9%*

Source: PIE Manufacturing Survey and Current Population Survey NBER Merged Outgoing Rotation Group (MORG) data.
Note: We have used employment weights for the PIE survey and individual earnings weights for the CPS.
*=significant differences at 95 percent level or higher.

We can see from examination of Table 1 that although there are a number of statistically significant differences between means in the two surveys, the magnitude of these differences is generally modest. Average wages for production workers are quite close, and both datasets show almost identical percentages of female production workers. The PIE survey has somewhat greater union representation among production workers (18 percent vs. 14 percent). In terms of age structure, the percentages of young (less than 30 years old) and old (56 years old or older) workers were very similar, while the PIE survey reports higher percentages of young middle aged workers (aged 31-40) than the CPS (28 percent vs. 22 percent). The CPS reports a

[7] We chose to validate our data with the CPS rather than with an establishment survey such as the Bureau of Labor Statistics' Current Employment Statistics (CES) survey because the CES includes working supervisors in its definition of production workers. As a result, wages and some other workforce characteristics are not comparable between the PIE survey and the CES.

correspondingly greater percentage of older middle aged workers. Overall, these differences are modest and imply that the PIE survey is faithfully capturing data on manufacturing production workers and the establishments at which they are employed.

Skill Demands

We can now turn to the question of what skills employers actually demand. It would not be informative to ask specific questions about skills or hiring that characterize the entire manufacturing workforce (production employees, managers, clerical workers, etc.) since no generalization would be accurate across the entire spectrum of jobs. Therefore, for questions concerning skills, demographics, and hiring, the survey asked respondents to answer based on their "core" workers. These were defined as the employees who are most critical to the production process (for other examples of this approach see Ben-Ner and Urtasun 2013 and Osterman 1995). Examples of occupational titles that respondents classified as core workers include manufacturing associates, fabricators, assemblers, production technicians, and process operators. We asked respondents to base their answers on permanent employees, as opposed to temporary staff or independent contractors. On average permanent core employees represented 63 percent of total employment in the survey establishments.

In the survey we posed a battery of concrete questions about the skills required to perform core production jobs. For example, with respect to reading skills we asked four questions: whether the job requires reading basic instruction manuals, complex technical documents, any document longer than five pages, or articles in trade journals. With regard to computers and technology, we asked whether the job requires skills ranging from internet search

capabilities to computer-aided design skills to computer-numerically controlled (CNC) programming.

We categorized skills in two groups: basic and extended. Basic skills involve lower level skill demands in each category, while extended skills involve elevated skill demands. For example, in the math category we defined basic math as addition/subtraction, multiplication/division, and fractions/decimals/percentages. Extended math consists of algebra, geometry, trigonometry, probability, statistics, calculus, and other advanced math demands. More detailed information on survey questions and design is available in Osterman and Weaver (forthcoming). Tables 2 and 3 contain the basic and extended skill results.

Table 2. Basic Skill Demands for Core Production Jobs

	All Establishments
Basic reading (ability to read basic instruction manuals)	75.6%
Basic writing (ability to write short notes, memos, reports less than one page long)	60.5%
Basic math (ability to perform all of math categories below)	74.0%
Addition and subtraction	
Multiplication and division	
Fractions, decimals, or percentages	
Require basic reading, writing, and math	42.4%
Require use of computers several times per week or more frequently	62.3%
Ability to use word processing software or ability to search Internet for information	41.7%

Demand for particular basic skills is widespread. Seventy-six percent of establishments require basic reading for their core production positions, while 74 percent require the ability to perform a bundle of basic math skills (addition/subtraction, multiplication/division, and fractions/decimals). Sixty-two percent of establishments require computer usage on at least a weekly basis, and 42% require either basic word processing or the ability to perform Internet searches for information. What is striking, however, is how modest these demands are. Only 42 percent of establishments require all of the basic reading, writing, and math skills.

With regard to extended skills, extended reading and extended computing are the most frequently demanded higher-level skills, with 53 percent and 42 percent of establishments requiring these for core production workers, respectively. By contrast, only 22 percent of establishments require higher-level writing. In addition to academic skills, we asked a question about whether the establishment required a unique skill that that other firms in the area do not require. About one quarter of establishments reported such a requirement.

As with basic skill demands, the extended skill demands are notable for their modesty, particularly with regard to math. Only 38 percent of establishments require at least one of the extended math skills (Table 3). The breakdown in math demands is even more revealing. While just under a third of establishments require algebra, geometry or trigonometry, only seven percent require calculus or other similar advanced mathematics. Thus even among some of the more demanding establishments, the math requirements for core production workers in America are mostly at a level that is attainable by a talented high-school graduate or, without question, a community college graduate.

After reading and math, computer capabilities are the next most commonly required higher-level skills. Twenty-eight percent of establishments require core workers to be able to use

computer-aided design or manufacturing (CAD/CAM) software, while a similar percentage require the use of some other type of engineering or manufacturing software. Only 19 percent require computer programming skills. Overall, 42 percent of establishments require some type of extended computer capability.

Table 3. Extended Skill Demands for Core Production Jobs

	All Establishments
Extended reading	52.6%
Extended writing	22.1%
Extended math (ability to perform any of three math categories below)	38.0%
Algebra, geometry, or trigonometry	31.5%
Probability or statistics	13.6%
Calculus or other advanced mathematics	7.4%
Extended computer	41.9%
Use CAD/CAM	28.4%
Use other engineering or manufacturing software	29.2%
Ability to write computer programs (such as program a CNC machine for a new piece, etc.)	18.6%
Unique skill	25.9%

Source: PIE Manufacturing Survey.

Although the skill debate in America frequently focuses on "hard," STEM-related skills, there is another line of thought that argues that soft skills—such as the ability to work in teams—are increasingly important to modern high-productivity production systems (Osterman 1995; Gale, Wojan, and Olmstead 2002; Heckman and Kautz 2012). In this view, demands have risen for both interpersonal skills and for skills involving worker initiative and problem-solving. We

asked a variety of questions to gauge the levels of demand in these areas. Table 4 contains the percentages of establishments that reported these various skills were "very important" for core production positions, as well as the percentages that reported either "very important" or "moderately important." The results contain several notable features. First, a large majority of manufacturing establishments—more than eight in ten—place high importance on cooperation with fellow employees. Just under two-thirds of respondents also selected the ability to work in teams as a critical skill for core workers. Two other skills that received high ratings were the ability to assess the quality of output, and the ability to take steps to fix quality problems. Seventy-one and 76 percent of establishments cited these quality-related

Table 4. Percent of Establishments Citing Interpersonal, Problem-Solving, and Other Soft Skills as Very or Moderately Important for Core Jobs

	Very Important	Very or Moderately Important
Cooperation with other employees	81.2%	99.3%
Ability to evaluate quality of output	71.0%	95.8%
Ability to take appropriate action if quality is not acceptable	76.3%	97.7%
Ability to work in teams	64.2%	91.1%
Ability to learn new skills	50.1%	89.3%
Ability to independently organize time or prioritize tasks	45.6%	84.4%
Ability to solve unfamiliar problems	38.8%	83.0%
Ability to critically evaluate different options	35.7%	74.1%
Ability to initiate new tasks without guidance from management	35.2%	80.9%

Source: PIE Manufacturing Survey. For significant differences between column results and all-establishment results: *=p-value<.10; **=p-value<.05; ***=p-value<.01 .

measures as very important. Thus interpersonal skills and quality assessment appear to be critical skills for core workers in production systems around the country.

The next notable feature about the results is the relatively low level of “very important” responses for skills that are often thought to be essential for modern high-tech, high productivity manufacturing. While eight out of ten establishments view solving unfamiliar problems or initiating new tasks without guidance as at least moderately important, less than 40 percent view these skills as very important for core production workers. Only half feel that the ability to learn new tasks is very important. The picture that these results provide of core production systems in U.S. manufacturing is one in which performing high-quality work in a cooperative fashion using existing procedures is important, but exercising creative problem solving or taking initiative is substantially less so.

There are several takeaways from these descriptive survey results on skill demands for core production workers. First, basic academic skills and interpersonal skills are important. Demand for basic levels of math, reading, and computer skills is widespread. Requirements for extended reading and computer abilities, in particular, are common, encompassing more than half of all manufacturing establishments. Cooperation and teamwork are also skills that large numbers of manufacturing establishments place great value on. However, at the same time, a substantial percentage of establishments have relatively low skill demands. Even among the plants requiring higher skill levels, the skill demands appear very attainable, particularly with regard to math. With regard to skills that are thought to be part of high-tech flexible manufacturing systems, emphasis on problem-solving, initiative, self-management and other skills appears surprisingly muted.

The Characteristics of Establishments that Demand Higher Skill Levels

Given the above concrete measures of skill demands, we can now explore what type of establishments demand higher skill levels. To accomplish this, we have created a binary variable that equals one if an establishment demands any of the extended skills (reading, writing, math, and computer) for its core worker positions. We have also created binary indicators for whether an establishment demands these skills individually, along with an indicator for the demand of a unique skill not required by other area plants. With these measures as dependent variables, we use a logit model to investigate the relationship between these extended skill demands and various organizational characteristics. These characteristics include an indicator for membership in a high-tech industry based on a Bureau of Labor Statistics methodology measuring the industry's proportion of scientific and research personnel (Hecker 2005).[8] They also include an indicator for above-average plant technology, measures of the percentage of a plant's core workers who are involved in Total Quality Management (TQM) or self-managed work teams, indicators for membership in an industry cluster as well as status as part of a larger firm, and an indicator that equals one if the establishment reported that it had more foreign than domestic competition. In addition, we have used two measures of innovation. The first is a binary variable that equals one if the organization reported that it engaged in more-than-incremental product innovation at least every two years or more frequently. The second is an equivalent variable measuring process innovation. Table 5 contains the results. We report marginal effects for these logit specifications.

The largest effects in terms of magnitude are associated with high-tech industry status. Establishments that were members of high-tech industries were 17 percentage points more likely

[8] Following Hecker (2005), we classify industries as high tech if the proportion of technology-oriented occupations (such as engineers, computer scientists, etc.) in the industry is at least twice the proportion of these occupations among all industries. Note that production workers are not included in this determination of high-tech status.

to demand any extended skill (reading, writing, math, or computer). This coefficient is significant at the 99 percent level. With regard to specific skills, high-tech plants had significantly higher probabilities of demanding extended reading and computer skills. Interestingly, high-tech establishments did not have significantly higher math demands. With regard to high-performance work (HPW) system variables, greater percentage involvement of core workers with TQM programs was associated with a significantly higher probability of demanding an extended skill, primarily as a result of higher computer demands. Extending TQM participation to 100 percent of a plant's workforce is associated with a ten percentage point increase in the probability of demanding extended computer skills. Similarly, extending self-managed work teams to the entire core production workforce implies a 20 percentage point increase in the likelihood of demanding extended reading skills, and a ten percentage point increase in the probability of extended math demands. These HPW effects are all significant at the 95 or 99 percent level.

Process innovation and membership in an industry cluster were also associated with significantly higher skill demands, although product innovation was not. Plants that engaged in frequent process innovation were 7.8 percentage points more likely to demand an extended skill, while cluster members had a 7.3 percentage point greater likelihood of doing so (both significant at the 95 percent level). Greater levels of foreign competition were associated with significantly higher math and computer skill demands, while being part of a larger firm was actually associated with significantly lower math and computer demands.

We have also included results for "unique" skill demands that are not required by other area plants. Plants reporting above-average technology or cluster membership were roughly nine

to ten percentage points more likely to demand unique skills. Increasing levels of self-managed work team participation were also associated with significantly higher unique skill demands.

Table 5. Establishment Characteristics Associated with Higher Skill Demands

	Any Extended Skill	Extended Reading	Extended Math	Extended Computer	Extended Writing	Unique Skill
High-tech industry	0.172***	0.288***	0.026	0.143***	0.025	0.006
	(0.032)	(0.038)	(0.039)	(0.043)	(0.036)	(0.037)
Above-average tech.	0.019	0.039	0.001	0.059*	-0.018	0.087***
	(0.032)	(0.035)	(0.033)	(0.036)	(0.030)	(0.032)
TQM pct.	0.001***	0.001	0.0003	0.001***	-0.0001	0.001*
	0.000	0.000	0.001	0.000	0.000	0.000
Self team pct.	0.001	0.002***	0.001**	0.0005	0.001	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)	0.000	0.000
Frequent product innovation	0.032	0.006	-0.06	-0.025	0.038	-0.014
	(0.037)	(0.041)	(0.040)	(0.041)	(0.034)	(0.038)
Frequent process innovation	0.078**	0.081**	0.076**	0.125***	0.02	0.036
	(0.037)	(0.040)	(0.037)	(0.040)	(0.034)	(0.036)
Industry cluster	0.073**	0.062*	0.066**	0.093***	-0.023	0.095***
	(0.030)	(0.034)	(0.032)	(0.034)	(0.029)	(0.031)
Part of larger firm	-0.025	0.01	-0.089**	-0.088**	0.029	-0.039
	(0.035)	(0.039)	(0.038)	(0.039)	(0.033)	(0.036)
More foreign competition	0.059*	0.062	0.112***	0.119***	-0.019	0.027
	(0.035)	(0.040)	(0.040)	(0.041)	(0.033)	(0.037)
Pseudo R-Squared	0.066	0.082	0.043	0.061	0.013	0.038
N	804	797	796	795	792	800

Source: PIE Manufacturing Survey. * p<0.10, ** p<0.05, *** p<0.01

Although there is a fair amount of heterogeneity in these results, the patterns are generally in line with expectations. High-tech and HPW plants demand significantly higher skill levels, as do members in industry clusters. The cluster results may stem partly from the fact the establishments in clusters have a greater tendency to specialize and hence to demand unique skills or unique variations on more traditional skills. The fact that process but not product

innovation is a strong predictor of high skill demands also makes sense. Core production workers are more involved with production processes than product design, and frequent changes to these processes may have more implications for skill demands than product innovation (which may not happen at the plant level). We would expect foreign competition to raise the pressure to automate and make capital investments, and indeed we see that such competition is associated with higher computer and math demands. Finally, large firms may have the resources to invest in production systems that routinize work and increase the division of labor, thereby lowering skill demands.

Hiring and Vacancies: Evidence on Skill Gaps

Business leaders and public officials have expressed considerable concern regarding a skill shortage, and this concern has been reflected in the debates in the academic literature over the role of structural mismatch in current high unemployment rates. Unfortunately, as we discuss above, the measures used by the current literature are generally noisy proxies, overly general aggregates, or opinion responses that do not allow for detailed insights into the degree to which employer skill demands are being met. We have specifically designed the PIE survey to remedy this shortcoming.

With regard to the hiring process, PIE Survey data suggest that most employers are able to find the workers they seek in a reasonable time frame (Table 6). The mean establishment in our survey required about six weeks to recruit and hire a core worker, while the median establishment required four weeks. Employers in the survey received an average of 24 applications per open position, and conducted six interviews per open position. The average acceptance rate by successful applicants was 85%.

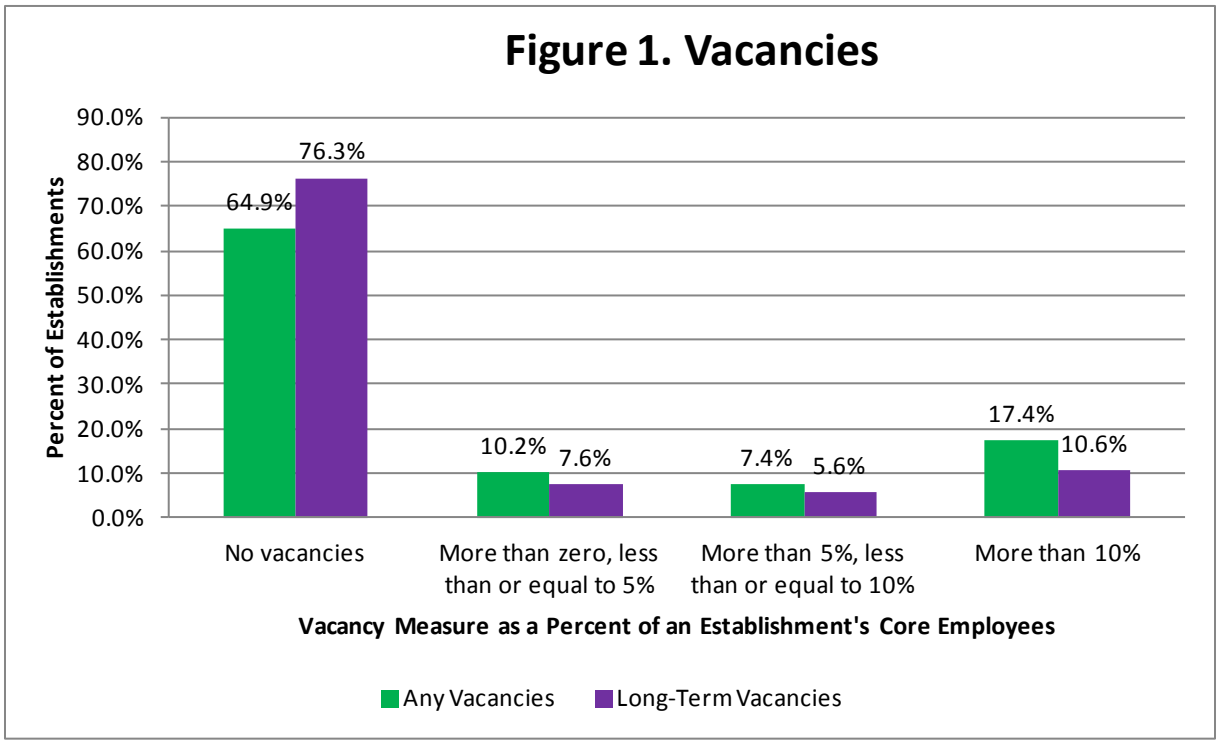
Table 6. Hiring Funnel for Core Workers

	Mean	Median
Weeks required to recruit and hire applicant (start of process to extension of offer)	5.9	4.0
Typical number of applications received per open core position	23.8	10.0
Typical number of interviews conducted per open core position	5.9	5.0
Acceptance rate by applicants who are extended an offer	85.4%	95.0%

Source: PIE Manufacturing Survey.

In order to probe more deeply regarding skill mismatch, we focus on vacancies among core production positions. Some positive level of vacancies is required for the smooth operation of the labor market, and therefore the presence of a vacancy for a given position at a particular point in time is not necessarily a sign of a problematic gap between demand and supply. To address this issue, we asked establishments about the number of current core production vacancies that had persisted for three months or more. We believe that such long-term vacancies are the best concrete measure of potential skill gaps. Even in the case of these extended vacancies, there are factors other than skill mismatch that can explain the existence of such a prolonged job opening. As Peter Cappelli (2012) has noted, in the face of weak product demand, some firms may advertise an open position while waiting for a truly extraordinary candidate to come along. Indeed, Davis, Faberman, and Haltiwanger (2012) have argued that the intensity with which employers searched for workers fell during the Great Recession. Nevertheless, this long-term vacancy measure represents a substantial improvement over the use of undifferentiated vacancies. Long-term vacancies can be viewed as an upper bound on the potential amount of skill mismatch.

Because signs of hiring distress vary across firms, we analyze both measures of whether an establishment experienced any vacancies as well as measures of vacancies as a percentage of total core workers. These can be thought of as measuring the incidence and severity of potential skill mismatch, respectively.



Source: PIE Manufacturing Survey.

Figure 1 contains data on the distribution of any core vacancies and the distribution of long-term vacancies. Nearly two thirds of establishments do not have any core worker vacancies, and 76 percent do not have any long-term vacancies. Just under eight percent of establishments have long-term vacancies that amount to between zero and five percent of the establishment's total permanent core workers. About sixteen percent of establishments experienced long-term vacancies at a level that was greater than five percent of their core workforces.

These results contrast greatly with the opinion surveys from non-random samples that have shaped the public debate about manufacturing skill gaps. While the Deloitte/NAM (2011) opinion survey finds that 74% of manufacturers suffer from a lack of skilled production workers, the PIE Survey data indicate that at most a quarter of manufacturing establishments show signs of hiring distress with regard to production workers. Similarly, the Deloitte survey reports that the median manufacturer has vacancies equivalent to five percent of its total workforce. Although our survey focuses on core workers and not the entire manufacturing workforce, it is worth noting that our data indicate that the median firm has zero core worker vacancies. Given that core workers are 62 percent of establishment employment, these results call into question both the incidence and severity of manufacturing skill gaps. We believe the PIE Survey data indicate that at most 16-25 percent of manufacturing establishments have signs of hiring distress that could potentially indicate structural mismatch.

The Relationship between Long-Term Vacancies, Skill Demands, and the Characteristics of High-Skill Establishments

In this section, we explore the predictors of hiring difficulties. We run two sets of models. The first set explores the relationship between long-term vacancies and higher level skill demands. The second set investigates the relationship between long-term vacancies and the types of manufacturing establishments that we have shown to have significantly higher skill demands. In both cases, we utilize two dependent variables. The first is a continuous measure of long-term vacancies as a percentage of total core workers. We use linear regression to estimate these models. The second is an indicator for the presence of any long-term vacancy among core workers. We employ logit specifications to estimate these latter models (we report marginal

effects). These two dependent variables can be thought of as measuring the severity and incidence of hiring difficulties, respectively.

In addition to running models with only skills or establishment characteristics as explanatory variables, we also run reduced form models that control for various factors that could shift the supply and demand for skills. We use the county unemployment rate from 2011 (the year before our survey results) as well as the county population density as supply controls. We use the percentage change in core employment over the past two years as a demand shifter. In addition, in some of the reduced form models we add controls for wage levels (standardized by Census division) and self-reported below-market wages. Because wages are clearly endogenous, we present the reduced form models both with and without the wage controls. All models use unweighted data but control for employment size via employee size-class fixed effects.

Table 7 contains the vacancy-skill demand results. In columns one and two, we can see that in the absence of covariates (other than employment size fixed effects) extended skill demands are associated with significantly greater hiring difficulties. Establishments with any extended skill demand have levels of long-term core worker vacancies that are 1.6 percentage points higher as a percentage of total core workers (significant at the 99 percent level). Similarly, extended skill demands are associated with a 7.3 percentage point increase in the probability of having any long-term vacancies (significant at the 95% level).

In columns three and four, we can see which skill demands are driving these results. Extended reading, extended math, and unique skill demands are all significant predictors of prolonged vacancies. Extended math demands, for example, are associated with a ten percentage point increase in the likelihood of an establishment experiencing core worker vacancies, while

Table 7. Long-Term Vacancies and Skill Demands

	Pct. LT vac.	Logit LTV	Pct. LT vac.--detailed skills	Logit LTV--detailed	Pct. LT vac.--detailed, red. form	Pct. LT vac.--detailed, red. form + wages	Logit LTV--detailed, red. form	Logit LTV--detailed, red. form + wages
Any extended skill	0.016***	0.070**						
	(0.006)	(0.033)						
Extended reading			0.012**	0.086***	0.012**	0.011*	0.088***	0.094***
			(0.006)	(0.032)	(0.006)	(0.006)	(0.033)	(0.034)
Extended writing			-0.002	-0.022	-0.005	-0.003	-0.022	-0.026
			(0.007)	(0.037)	(0.007)	(0.007)	(0.037)	(0.038)
Extended math			0.017***	0.103***	0.016**	0.019***	0.098***	0.118***
			(0.006)	(0.037)	(0.006)	(0.006)	(0.038)	(0.039)
Extended computer			0.007	-0.02	0.006	0.007	-0.019	-0.011
			(0.006)	(0.033)	(0.006)	(0.006)	(0.033)	(0.034)
Unique skill			0.013**	0.086**	0.014**	0.015**	0.094**	0.108***
			(0.006)	(0.036)	(0.006)	(0.006)	(0.037)	(0.038)
New skills			-0.002	0.049	-0.003	-0.003	0.038	0.042
			(0.006)	(0.032)	(0.006)	(0.006)	(0.033)	(0.033)
Evaluate quality			0.001	-0.048	0.001	0.002	-0.047	-0.053
			(0.006)	(0.036)	(0.006)	(0.006)	(0.037)	(0.037)
County pop. density					0.000	0.000	0.000	0.000
					(0.000)	(0.000)	(0.000)	(0.000)
County unemp. rate (2011)					-0.123	-0.116	-0.872	-0.763
					(0.117)	(0.119)	(0.697)	(0.704)
Pct. change in core emp. over 2yrs.					-0.004	-0.008**	0.036	0.037
					(0.003)	(0.004)	(0.024)	(0.025)
Standardized division wage						-0.003		-0.029*
						(0.003)		(0.017)
Low wage						0.121***		0.169
						(0.031)		(0.154)
R-Squared/Pseudo R2	0.025	0.023	0.052	0.053	0.054	0.082	0.057	0.060
N	869	870	831	832	808	778	808	778

Source: PIE Manufacturing Survey. * p<0.10, ** p<0.05, *** p<0.01

extended reading demands predict a nine point rise (both significant at the 99 percent level).

Interestingly, computer skills are not significantly associated with hiring difficulties. Although

we have only included a couple of the problem-solving/soft skills, in other specifications none of these additional skill measures had significant effects.

The reduced form models contain similar results, with coefficients and significance levels remaining largely unchanged. As expected, higher unemployment is associated with lower levels of prolonged vacancies, although the coefficients are insignificant. On the demand side, greater percentage increases in core workers over the past two years has mixed and mostly insignificant effects. The signs of the wage variables are consistent with expectations. Higher regional wages are associated with lower hiring difficulties, while self-reported below-market wages are associated with greater incidence and severity of long-term vacancies. Only the below-market severity effect is significant, however.

Taken together, these results indicate that demands for extended math and reading skills, along with firm-specific unique skills, are significant predictors of hiring difficulties. Thus we find support for the idea that skill demands are associated with hiring difficulties, although the effect is limited to a small range of skills. However, before we draw any conclusions about the nature of this relationship, it is important to examine the experience of various types of establishments that have high skill demands.

Table 8 contains the vacancy-establishment characteristics results. As we noted in the empirical strategy section above, if hiring difficulties are a simple function of skill demands, then establishment types with significantly higher skill demands should mechanically have significantly greater signs of hiring difficulties. We again use two dependent variables: long-term vacancies as a percentage of total core workers (estimated by linear regression) and an indicator for the presence of any long-term vacancies (estimated by a logit model).

Table 8. Long-Term Vacancies and Establishment Characteristics

	Pct. LT vac.	LTV--Logit	Pct. LT vac.--RF	Pct. LT vac.--RF+wage	LTV--Logit--RF	LTV--Logit--RF+wage
High-tech	-0.01	-0.052	-0.014**	-0.017**	-0.068*	-0.072*
	(0.007)	(0.038)	(0.007)	(0.007)	(0.037)	(0.039)
Above-avg. tech.	-0.001	-0.019	-0.001	-0.001	-0.024	-0.026
	(0.006)	(0.033)	(0.006)	(0.006)	(0.033)	(0.034)
TQM pct.	0.000	0.001	0.002	0.003	0.004	0.005
	(0.000)	0.000	0.000	0.000	0.000	0.000
Self team pct.	0.000	0.001	0.002	0.003	0.004	0.005
	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)
Product innovation	0.002	0.019	0.001	0.003	0.018	0.022
	(0.007)	(0.038)	(0.007)	(0.007)	(0.039)	(0.040)
Process innovation	0.000	0.005	0.002	0.003	0.013	0.021
	(0.007)	(0.038)	(0.007)	(0.007)	(0.038)	(0.039)
Industry cluster	0.017***	0.119***	0.014**	0.013**	0.117***	0.117***
	(0.006)	(0.032)	(0.006)	(0.006)	(0.032)	(0.033)
Part of larger firm	0.003	0.024	0.003	0.001	0.032	0.031
	(0.007)	(0.037)	(0.006)	(0.007)	(0.037)	(0.038)
More foreign comp.	0.002	0.019	0.001	0.001	0.027	0.025
	(0.007)	(0.038)	(0.007)	(0.007)	(0.039)	(0.039)
County pop. density			0.000	0.000	0.000	0.000
			(0.000)	(0.000)	(0.000)	(0.000)
County unemp. rate (2011)			-0.148	-0.129	-0.795	-0.695
			(0.122)	(0.124)	(0.711)	(0.721)
Pct. change in core emp. last 2 yrs.			-0.011***	-0.012***	0.016	0.016
			(0.004)	(0.004)	(0.024)	(0.025)
Standardized division wage				0.003		0.005
				(0.003)		(0.017)
Low wage				0.121***		0.18
				(0.032)		(0.160)
R-Squared	0.036	0.034	0.050	0.073	0.040	0.038
N	783	784	766	738	766	738

Source: PIE Manufacturing Survey. * p<0.10, ** p<0.05, *** p<0.01

Columns one and two present results for models with these two dependent variables that contain only establishment characteristics as explanatory variables. The subsequent columns present

reduced form models for the two outcome measures with the same supply and demand controls described above. These results are presented both with and without wage controls due to the endogeneity of wages.

The results are notable for several reasons. First, while many establishment characteristics are significantly related to higher skill demands (Table 5), they are generally not significantly related to long-term vacancies. While this is perhaps not surprising for the characteristics that are linked to skills that are not predictive of long-term vacancies, even characteristics that are linked to higher demand for extended reading, extended math, and unique skills do not show significantly greater signs of hiring distress. Self-managed work team coverage, frequent process innovation, membership in a larger firm, more foreign competition, and above-average plant technology all have small and insignificant coefficients. Establishments in high-tech industries, which had some of the highest skill demands, actually have significantly lower severity of long-term vacancies in the linear reduced form models. High-tech establishments have levels of long-term vacancies that are 1.4 percentage points lower as a percentage of total core workers (significant at the 95 percent level). The sole exception to this pattern is membership in an industry cluster. Establishments that are part of clusters are 12 percentage points more likely to experience long-term vacancies and have extended vacancy percentages that are 1.3-1.4 percentage points higher than their non-cluster peers (results significant at 95 percent level or above). As we mentioned above, part of the industry cluster effect may relate to the specialization of skill demands as opposed to the absolute level of these demands.

Results are generally stable across the wage and no-wage versions of the reduced form specifications. With regard to control variables, the unemployment/supply measure continues to

have the expected negative relationship with vacancies (although it is not significant). The direction of the demand effect varies between the two models. For the linear models increasing demand is now significantly associated with a lower percentage of long-term vacancies. Below-market wages continue to imply large and significant percentage point increases in the severity of hiring difficulties. On balance, these results do not support the hypothesis that both higher skill demands and high-skill establishments will be significantly associated with greater signs of hiring difficulties if such difficulties are a simple function of inadequate worker skills.

Discussion of Long-Term Vacancy Regression Results

Overall, these long-term vacancy results qualify our view of skill mismatch. Even among the minority of manufacturing establishments that do show potential signs of hiring distress, the relationship between skill demands and hiring problems is not simple or clear-cut. Many higher skill demands, including those for soft skills and problem-solving/initiative skills, are not associated with hiring difficulties. Extended math and reading skills are important predictors of long-term vacancies, but the relationship is not a mechanical one. Many of the types of establishments with the highest skill demands—such as high-tech plants—do not have significantly higher incidence or severity of long-term vacancies. This finding implies that other factors mediate the relationship between skill demands and hiring problems, and that one does not automatically lead to the other.

Identifying these factors is a promising topic for future research. There are a number of potential explanations for why high-tech and other plants might have significantly higher skill demands but not significantly greater hiring problems. First, managerial strategy may make a difference. Some industries or plant types may be characterized by more competent or forward-

looking managers who are able to more effectively address human resource challenges. Second, the quality of the institutional environment and institutional relationships may help determine why some high skill demands result in long-term vacancies while others do not. Some regions may have better intermediaries that link firms and workers, and some firms may have better relationships with local entities such as community colleges. Finally, employees may differentially supply their labor to industries or types of establishments that have attractive characteristics or more promising futures. The fact that these mediating factors seem to be important leaves ample room for both firm-level strategy and public policy interventions that go beyond simply asking workers to make behavioral changes regarding educational attainment.

Conclusion

Assuring the balance of supply and demand for labor in the economy is critical for economic growth as well as economic opportunities for workers. The elevated unemployment rates in the recent recession have heightened debate over whether structural mismatch is driving poor labor market outcomes. One of the most common claims is that employers cannot find the skilled workers they seek due to gaps between skill demands and supplies in the labor market. Unfortunately, the existing literature tests for mismatch by relying on highly aggregated data and noisy proxies that obscure underlying mechanisms as well as the degree to which mismatch takes place within industries. Measuring within-industry effects is important since much of the increases in skill demands and unemployment have taken place at the intra-industry level (Modestino 2010; Lazear and Spletzer 2012). We address these issues by presenting and analyzing results from a survey of U.S. manufacturing establishments. Our survey is the first, to

our knowledge, to directly measure concrete employer skill demands and hiring experiences in a nationally representative survey at the industry level.

We measure skill demands by asking concrete questions about the specific skill requirements for core production jobs. We quantify skill gaps by measuring the number of vacancies among core production workers that have persisted for three months or more. We find that basic skill demands are widespread, but that demands for higher level skills are surprisingly modest. Demands for higher level reading and math skills are prominent, but those for skills related to high-performance work systems are substantially less so. With regard to skill gaps, three quarters of establishments show no sign of hiring difficulties. We estimate an upper bound on potential skill gaps of 16-25 percent of manufacturing establishments. This finding contrasts sharply with other, non-representative surveys that have reported figures in excess of 60 or 70 percent (Deloitte 2011).

We also explore the characteristics associated with both skill demands and long-term vacancies. We hypothesize that if hiring difficulties among the quarter of establishments with long-term vacancies are a simple function of skill demands exceeding workforce skill supplies, then long-term vacancies will be significantly associated with *both* higher skill demands and the types of establishments that we show to have significantly higher skill demands. We find that long-term vacancies are significantly associated with higher reading and math demands, but not significantly associated with almost all of the establishment types that have higher skill demands. In particular, high-tech plants have significantly higher skill demands, but they have significantly lower long-term vacancies as a percentage of total core workers. We interpret this finding to indicate that other factors mediate the relationship between skill demands and hiring difficulties, and that simple stories about inadequate worker skills driving skill gaps are misleading.

The fact that mediating factors are important potentially opens up a productive role for firm-level strategy as well as policies targeted at a variety of institutional factors. If it were the case that hiring problems were the mechanical result of under-trained workers who simply cannot meet the skill demands of modern industry, then the range of solutions and responses would be limited to large-scale structural interventions involving broad improvements in the educational system, coupled with hand-wringing about why workers do not seem to respond to employer signals about increasing skill and education levels. By contrast, the heterogeneity of these results implies that managerial strategy may be able to improve hiring outcomes. Such strategy could involve greater outreach to nontraditional populations, increased internal training, or improving an individual firm's linkages with the local community college system. Even if differential labor supply due to worker fears about the volatility of particular industry sub-sectors ends up being an important factor, the range of institutional interventions to lower the risk of making certain career choices is much wider than the general calls for increased education resulting from the mechanical skill gap view. Likewise, the protracted vacancies associated with the unique and specialized skills of firms located in industry clusters point to tailored training solutions and improved institutional relationships rather than strategies to address broad workforce inadequacies. Of course, it is important to improve our understanding of the phenomena behind hiring difficulties in order to design appropriate firm and institutional responses. We feel that investigation into the nature of these mediating factors is a fruitful area for future research.

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