

Draft

The Influence of Licensing Engineers on their Labor Market*

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Abstract

Our paper presents a comprehensive analysis of the role of occupational licensing requirements on the labor market for civil, electrical, and industrial engineers. These groups of engineers represent the largest number of engineers that are covered by occupational licensing statutes in the United States. We initially trace the historical evolution of licensing for engineers. Second, we present a theoretical rationale for the role of government in the labor market for the occupation. In the model, the government's ability to control supply through licensing restrictions and the pass rate could limit the number of engineers, which may drive up wages. We then estimate a panel data model for the engineers in our sample using the American Community Survey and regulatory statutes. Our estimates show a small influence of occupational licensing on both wages and hours worked in a variety of specifications and sensitivity analysis tests.

Shortages and surpluses of engineers are a recurrent labor market problem in the United States, which have attracted considerable public and professional attention. (Freeman, 1976)

Introduction

Analysts of the labor market for engineers have often documented the phenomenon of recurring booms and busts (Hansen, 1961; Folk, 1970; Freeman, 1976). One potential public policy solution has been to regulate the market for engineers, especially ones that require licenses to practice within the occupation and thereby reduce market volatility for engineers. With regulation and planning, perhaps these wide swings, which result in uncertainty for both employers and those considering entering the occupation, could be reduced. Besides the stated public policy rationale that labor market regulation improves public health and safety, it also may serve to reduce fluctuations in the market for engineers. Licensing may create a “web of rules” that results in a more orderly functioning of the labor market for the occupation that reduces uncertainty and variance in quality (Dunlop, 1958). Further, engineers and the functioning of their labor markets are viewed as important contributors to innovation and economic growth. An analysis that sheds light on the functioning of these labor markets may contribute to an understanding of how institutional factors influence engineering’s contribution to technological change. However, if the influence of licensing for engineers is similar to markets for other regulated occupations, it may then restrict the supply of labor, causing an increase in wages and a reduction in the utilization of engineers in production (Kleiner and Kudrle, 2000; Kleiner and Todd, 2009).

The general policy issue of occupational licensing is an important and growing one in the U.S. labor market, since it is among the fastest-growing labor market institutions in the U.S.

economy. For example, in the 1950s about 4.5 percent of the workforce was covered by licensing laws by state government (Kleiner, 2006). By 2008 approximately 29 percent of the U.S. workforce had attained licensing by any level of government, and by the 1990s more than 800 occupations were licensed by at least one state (Brinegar and Schmitt, 1992; Princeton Data Improvement Initiative (PDII), 2008; Kleiner and Krueger, 2013). This figure compares with about 12.6 percent of the members of the workforce who said they were union members, another institution that looks after its members, in the Current Population Survey (CPS) for the same year; that value was down 11.3 percent by the end of 2012 (Hirsch and Macpherson, 2011; U.S. Department of Labor, 2013). Although we do not have information on the trends for the licensing of engineers, their level of unionization has declined, which is consistent with national trends. Figure 1 shows the decline in unionization for civil, electrical, and industrial engineers from 1983 to 2010. The steepest dip was for electrical engineers, where unionization declined from about 12.2 percent in 1983 to 4.8 percent in 2010. The smallest decline was for industrial engineers, whose rates of unionization declined from 9.2 percent to 8.3 percent over the same time period. We will focus our analysis on these engineering specialties for this paper, since they represent a continuum of more to less regulated specialties in engineering.

Since occupational regulation has many forms, describing its various types is worthwhile. The occupational regulation of engineers in the United States generally takes three forms. The least restrictive form is registration, in which individuals file their names, addresses, and qualifications with a government agency before practicing their occupation. The registration process may include posting a bond or filing a fee. In contrast, certification permits any person to perform the relevant tasks, but the government—or sometimes a private, nonprofit agency—administers an examination or other method to determine qualifications and certifies those who

have achieved the level of skill and knowledge for certification. For example, travel agents and car mechanics are generally certified but not licensed. The toughest form of regulation is licensure; this form of regulation is often referred to as “the right to practice.” Under licensure laws, working in an occupation for compensation without first meeting government standards is illegal. Our analysis provides a first look at the role of occupational licensing, rather than the other two forms of governmental regulation in the labor market for engineers in the United States.

We examine the role for occupational licensing in the labor market for engineers from 2001 through 2012. Initially, we present the evolution and anatomy of occupational licensing for engineers. Next, we present a theory of licensing and show how this form of regulation leads to wages dropping to the competitive wage as the licensing authority increases the supply of practitioners. In the following section, we show the data for the analysis and present the growth of regulation for the three types of engineers in our data set. Next, we present our empirical analysis for three large specialties in engineering—civil, electrical, and industrial—when variations in occupational licensing characteristics such as examinations and pass rates are included. In the final section, we summarize our results.

The theoretical model shows that government-granted licenses to protect the public can also lead to rents for the members of the occupation. As more individuals are allowed into the occupation by the planner, wages fall. To the extent that regulation reduces innovation and that unregulated members of the occupation can do higher wage tasks, regulation may diminish wages. The estimates in our models are small for the labor market effects of licensing, and they depend on the requirements and the engineering specialty examined. Also, some evidence indicates that some licensing requirements influence the number of hours worked by engineering

specialty. The studies of the influence of licensing statutes on labor market outcomes perhaps need better data on individuals who have a license rather than just state licensing coverage, since coverage biases downward the influence of this type of regulation (Gittleman and Kleiner, 2013). In this study we focus on licensing coverage rather than attainment, since determining attainment is possible only when individual data explicitly ask whether an individual was licensed.

The Evolution and Anatomy of Licensing for Engineers

Similar to other occupations that eventually became licensed, such as dentists and nurses, the government regulation of engineers began in the early 1900s (Council of State Governments, 1952). The first state to pass a licensure law was Wyoming in 1907. At the time, Wyoming engineers were concerned with water speculators who lacked the qualifications or experience of trained engineers but nonetheless used the term “engineer.” The law was passed so that “all the surveying and engineering pertaining to irrigation works should be properly done” (Russell and Stouffer, 2003, p.1). The American Society of Civil Engineers (ASCE) supported this piece of legislation, but otherwise resisted the notion of state-controlled licensing. After 1910, many civil engineering associations supported the concept of state licensing in order to control specific aspects of the practice that would be regulated. The ASCE promulgated a model law for licensure in 1910. This shift in policy also helped the occupation of civil engineering to be consistent with regulations that were being developed in other professions such as medicine and law, which had already accepted licensure (Haber, 1991; Pfatteicher, 1996).

Around 1920, the National Council of State Boards of Engineering Examiners was formed to work for licensure in every state, help enforce regulations, and ensure appropriate levels of experience and education for professional practice. This organization evolved into the National Council of Examiners for Engineering and Surveying (NCEES). As more states adopted

regulations for professional practice, these engineering associations also became involved in advocating for the standardization of engineering curricula in professional schools and universities. It took nearly 45 years for all 50 states to require licensure for the practice of civil engineering, although these licenses were required only for certain types of tasks that engineers perform.

In contrast, chemical, electrical, mechanical, and petroleum engineering were recognized as title holders and were covered by licensing following World War II. In the 1960s, industrial engineering was recognized as a title branch and was also regulated. Table 1 shows the percentage of engineers licensed by specialty in the United States, according to the National Council of Examiners for Engineering and Surveying (NCEES) in 1995 and from the Survey of Income and Program Participation (SIPP) for 2012. Civil engineering was by far the most regulated branch of engineering, with more than 44 percent of those practicing being licensed in 1995. This value declined to 31 percent in the SIPP in 2012. As the estimates in Table 1 show, about 9 percent of the electrical engineers were licensed in the mid-1990s and in 2012, and about 8 to 9 percent of industrial engineers were licensed in the mid 1990s and in 2012. This suggests large variance in the amount of regulation in the occupation of engineering. Moreover, the vast majority of engineers are covered by licensing statutes, but do not attain a license.

To measure the level of difficulty that each of the states sets for becoming a professional engineer, we develop an index of restrictiveness of engineer regulation. Not only has the level of licensing increased, but also the intensity of the process of becoming licensed has become more difficult. Based on conversations with key officials at the NCEES, as well as with focus groups comprising engineers, architects, and interior designers, we have identified the following central items as important in becoming licensed: a general age/education requirement, experience

requirements, a written exam, a practical performance exam, a specific engineering specialty exam, reciprocity requirements from other states, and a continuing education requirement.¹ These elements are the basis of an index of the rigor of the licensing process, in addition to the type of licensing. Using this index, we can trace the evolution of the intensity of the licensing index in the period 1995–2012. Table 3 summarizes the index of licensing regulations for engineers. The results show a slight upward movement in the mean values and a narrower spread in the variance of the licensing provisions across states. Occupational licensing is growing among states, and its provisions to enter and maintain good standing as a licensed professional engineer are becoming more stringent.

The nation's umbrella engineering licensing body embraced a so-called Model Rule that would extend by 30 the number of extra credit-hours BS-degreed engineers must have to gain a professional license, but no state licensing board has made it a reality. However, the deadline for the professional association is in 2020. The goals of the licensing groups are to increase the status of engineers. For example, Blaine Leonard, former ASCE president and supporter of the increased requirements for becoming a licensed engineer, stated the following: "If we want to meet challenges and be prepared to protect the public, engineers need more depth of knowledge. You can't get it in programs under pressure." Proponents would like to see engineering attain the same professional status as medicine and accounting. The National Academy of Engineering and the National Society of Professional Engineers support the idea," (Rubin and Tuchman, 2012).

Basic Theory

¹ We met and discussed with officials at the Minnesota Board of Architecture, Engineering, Land Surveying Landscape Architecture, Geoscience and Interior Design (AELSLAGID) regarding key criteria for licensing in that state and with several licensed engineers in Minnesota, Arizona, and California.

To provide a theoretical context for our empirical work, we first review a model of the influence of licensing on the supply of labor. In the following section, we focus on the demand for labor and how government can be an important factor within a licensing model. The analysis of wage determination under licensing in engineering builds on work by Perloff's (1980) work on the influence of licensing laws on wage changes in the construction industry. The basic model posits that market forces are largely responsible for wage determination and that demand for work is highly cyclical. This approach would also apply to the engineering labor market. Perloff presents two cases. In the first, there are no costs to shifting across industries so that labor supply is completely elastic at the opportunity wage. In this case, the increase in the demand for work would have little effect on wages, since workers would flow between varying industries. The introduction of a licensing law renders the supply of labor inelastic. In this case, labor cannot flow between the sectors so that variations in demand would be reflected in the wage. In his empirical work, Perloff shows that for electricians, more so than for either laborers or plumbers, state regulations make the supply curve highly inelastic. Consequently, the ability of a state to limit entry or impose major costs on entry through licensing would enhance the occupation's ability to raise wages. We would expect that a similar approach would apply to the market for engineers, with more inelastic supply curves for civil engineers relative to electrical and industrial engineers.

Unlike the work that has been developed on the supply side, relatively little analysis has been done on how degrees of restriction of labor supply with occupational licensing influence wages and the amount of work, and how such restrictions of supply can make the labor market deviate from a competitive market. Our model focuses on the supply restriction of labor, and

we develop a general model that we will apply to the regulation of engineers. We develop a model as follows:

Let $Q \equiv \sum_{i=1}^n q_i$, where q_i is each engineer's work output, n is the number of engineers in the

market, and Q is the total quantity of supply. Each engineer's monetary utility function is

$U_i = q_i P(Q) - D_i(q_i)$, where D denotes the engineer's disutility and P is the price of work output

(i.e. wage). The first-order condition for utility maximization is $P(Q) - D_i'(q_i) + q_i P'(Q) = 0$.

From the above equation, we have $\frac{P(Q) - D_i'(q_i)}{P} = \frac{\frac{q_i}{Q}}{\frac{P}{P'(Q)Q}} = \frac{\alpha}{\varepsilon}$ (1), where $\alpha \equiv q_i / Q$ is

engineer i 's market share, and $\varepsilon \equiv -\frac{P}{P'(Q)Q}$ is the elasticity of demand. Thus, the gap between

price and marginal disutility is proportional to the engineer's market share and inversely

proportional to the elasticity of demand. Price exceeds the engineer's marginal disutility as long

as α is non-zero. The larger the difference, the more prices deviate from the socially efficient

price.

For instance, for the symmetric case in which every engineer has the same output, with linear demand, $P(Q) = I - aQ$ for all i , and the convex disutility function being $D = bq + cq^2$. We assume that a, b, c are greater than zero, so that the demand is inversely related to price and the disutility is a convex function. The first-order condition of the engineer's utility maximization becomes $1 - aQ - b - 2cq_i - aq_i = 0$. The equilibrium is symmetric for this model: $Q = nq$, where

q is the output per engineer. Hence, we obtain $q = \frac{1-b}{an+2c+a}$ (2). The market price is

$$p = b + \frac{(1-b)(2c+a)}{an+2c+a} \quad (3), \text{ and each engineer's utility is } U = \frac{(1-b)^2(a+c)}{(an+2c+a)^2} \quad (4).$$

The number of engineers, n , is an exogenous variable in the model. It is decided by the restrictions such as an examination requirement and the pass rate for the licensing exam. The stricter the licensing examination, the smaller the n . Equations 2 to 4 show that when the licensing requirement is stricter, the incumbent engineers' wage, output per person (measured as work hours in the empirical section), and utility will all increase.

From the above results and Equation 1, we have $\frac{P(Q) - D_i'(q_i)}{P} = \frac{\alpha}{\varepsilon} = \frac{a(1-b)}{abn+2c+a}$. So

another implication of the model is that the fewer the number of engineers, the further the wage will deviate from the socially efficient wage ($p = D'(q_i)$). Conversely, when the number of engineers becomes very large ($n \rightarrow \infty$), the wage tends to become the competitive wage. This would be the case when other unlicensed engineers can largely serve as substitutes for regulated engineers.

Data, Model, and Estimation

Using the above model as our guide, we now present the details of the information on the regulations facing engineers and the labor market conditions of the three broadly representative types of engineers: civil, electrical, and industrial. We chose these types of engineers because they reflect a continuum of regulation ranging from civil engineers who are the most regulated, electrical engineers less so, and industrial engineers the least regulated by state statutes. Table 2 displays the key elements (and their operational definition) of the licensing provisions in the

statutes and administrative provisions that we plan to examine for each of the states in our sample for engineers.

Table 3 shows the yearly growth in the occupational licensing statutes index over the period 1995–2012. The results indicate that the occupation experienced growth in regulations governing entry and training requirements. The level of the index or the number of items included in the state level measure grew from 6.94 to 7.25, or by about 4 percent over this time period. This reflects the intensity of the growth of requirements to enter and maintain the status as a licensed engineer. Further, the standard deviation declined by almost 23 percent, suggesting greater standardization of the requirements for licensing across states and over time.

Table 4 shows the relative ranking of the states that have the highest and lowest values in the index. We also developed values that were established through an expert systems focus group approach to test the sensitivity of the results to alternative methods of evaluation. In this approach, an engineering student and a law student were given the data and asked to rank the states based on issues that were personally important to them as professionals in their respective fields. There was a high degree of consistency for the empirical and qualitative approaches. For many states, we were able to obtain the pass rates for the licensing examination for engineers². Figure 2 shows the states and time trend in years for which we were able to obtain from the licensing boards of each of the states that posted their overall engineering pass rates.³ The plots in the figure show that California has the lowest steady-state pass rate for the engineering exam, averaging about 40 percent per year. In contrast, the pass rate for the licensing of engineers in

² The links to the boards were available at <http://nces.org/licensing-boards>. We went to the data from each state to obtain pass rates.

³ The Tables A1 and A2 in the Appendix show the influence of the variations in the pass rates and the influence of the statutory provisions of test requirements on both wages and hours of work for a limited number of states in which the data were available.

Idaho is well above 80 percent. Unfortunately, no systematic national estimates could be developed because of the state data limitations over time and across states.

Economic Data

As a key part of our examination of the influence of regulation on the labor market for engineers, we use data from the American Community Survey (ACS) from 2001 through 2012. Table 5 presents the basic information that we used for our analysis. These variables include the standard variables from the ACS to include Mincer-type human capital variables such as gender, age, experience, education, and race. Unfortunately, no data on union status are available in the ACS. The means and standard deviations for the basic variables in the ACS are included in Table 5 by type of engineer. They show that there are small differences in human capital characteristics such as age, experience, or education across engineering specialties. However, the percentage of civil engineers who work for the government (about 24 percent) and are self-employed (about 5 percent) is much higher than in the other two types of engineering subgroups. The hourly earnings of electrical engineers (about \$37 per hour) are the highest of the three categories. Generally, the licensing requirements for civil engineers have been in force the longest and are the most detailed across states. The estimates for hours worked are also derived from the ACS. Since there are more observations over time for civil engineers, we have information for all states and years for this category. For electrical and industrial engineers, however, some state and year observations are missing in the ACS, so states such as Wyoming, Hawaii, Montana, and South Dakota are missing observations for a couple of years in our sample.

Wage Determination

Our empirical strategy is to first examine the three categories of engineers—civil, electrical, and industrial—that may vary greatly by the type of regulation that influences their ability to find employment. We estimate the model using all engineers in the categories together and then estimate wage equations for each group separately. In Figure 3 we show kernel density plots for the three types of engineers in our study. The results show that electrical engineers have the highest mean value for wages and the widest distribution of earnings among the three types of engineers we study, but industrial engineers have the lowest mean value.

Our basic model uses an earnings function and compares the three types of engineers (the least regulated one—industrial engineers—is the excluded category). Our basic model is of the following form:

$$1) \ln(\text{Earnings}_{ist}) = \alpha + \beta R_{st} + \gamma X_{ist} + T_{sti} + \delta_s + \theta_t + \varepsilon_{ist},$$

where Earnings_{ist} is the hourly earnings of engineer i at state s in year t ; T_{sti} is the type of engineer (civil, electrical, or industrial) for person i 's state s in year t ; R_{st} is the occupational licensing regulations (and its components) in person i 's state s in year t ; X_{ist} is the vector that includes covariates measuring characteristics of each person; δ and θ are state and year fixed effects, respectively; and ε_{ist} is the error term in our panel data.⁴

The model is a basic fixed effects approach that can also be viewed as a generalization of the conventional two-group two-period difference-in-difference model.⁵ The estimates presented in the tables show the results for both a traditional panel estimate using individuals as the unit of observation of the role of regulation on wage determination and a two-stage estimation procedure. For the two-stage procedure, the first stage is developed by estimating a model of

⁴ The use of a Rasch measure resulted in no basic effect of regulation on either wage determination or hours worked; consequently, we use the summated rating scale.

⁵ We also included time-varying state-level controls, such as the state median household income, but found that they have no explanatory power. Consequently, we do not show the results in this paper.

individual-level outcomes on covariates and a full set of state x (\times) time fixed effects. The coefficients on the state x (\times) time fixed effects represent state x time mean outcomes that have been purged of the variation associated with the within-cell variation in the covariates. In the second stage, these adjusted cell level means are estimates on the policy variables and fixed effects. The two-step approach is a way of performing aggregation while still allowing for adjustment of individual-level covariates, which is a limitation of the pure aggregation. The basic panel estimates include individual covariates as well as state and year fixed effects.⁶

Table 6 shows estimates from the model developed from the overall licensing index on wage determination using both the individual observations and the two-level analyses with controls. Since the index is an imprecise measurement of regulation, we develop a relative measure of regulation of high, medium, and low levels of regulation using our index. We then compare the highest levels of regulation relative to the low and medium ones. The first column shows the basic bivariate relationship between having the most restrictive licensing statutes and wage determination with the full sample of the ACS. The basic relationship shows a statistically significant 2 percent effect⁷. However, in the second column when human capital and state specific covariates are included, the estimates are still positive but small and not statistically significant. In examining the various engineering specializations in columns 3 through 8, we can see that there is some variation. For example, the bivariate estimates for civil engineers show a positive but small influence of being in a state with the most stringent regulations in the first stage, but no effect in the second stage. Similarly, for both electrical and industrial engineers, the engineering regulations have a small but positive effect in the first stage bivariate estimates,

⁶ The standard errors for these models were computed using a Huber-White covariance matrix that allowed for clustering at the state level.

⁷ We also estimated models that examined the influence of tougher licensing before and after the great recession of 2008, and found results similar to those presented in Tables 6, 7, 9 and 10.

but no influence in the second stage results. The significant estimates range from a high of 4 percent with no covariates for industrial engineers with no covariates to no effect in the fully specified model. The categorical specifications show regulation for engineers has a small effect that is close to zero. This is not unlike some of the specifications of the influence of unions on wage determination for other professional organizations (Lewis, 1986). Moreover, we only have estimates of licensing coverage and not those who have attained a license, which may bias our results downward (Gittleman and Kleiner, 2013). However, licensing requirements may also have effects on the supply of hours to the market.

The models developed for hours of work use approaches similar to the ones developed for our wage equation models. In a similar manner, we examine employment growth for each of the categories of engineers from 2001 to 2012. The basic model is of the following form:

$$\ln(E_{ist}) = \alpha + \beta R_{st} + \phi T_{ist} + \gamma X_{ist} + \delta_s + \theta_t + \epsilon_{ist}$$

where $Employment_{ist}$ is hours of work per week per engineer in state s in time period t for individual i ; T_{ist} is the type of engineer at state s in time period t for individual i ; R_{st} is the regulation measure and its components at state s in time period t ; the vector X_{st} includes covariates measuring economic and human capital characteristics within each state; δ_s and θ_t are state and year fixed effects, respectively; and ϵ_{ist} is the error term.

Table 7 gives the basic results for the impact of the licensing index on hours of work supplied by engineers using the specified model using categorical measures of regulation of high relative to low or medium. The results are consistent in showing that regulation is associated with an increase in hours worked by about 1 percent in the bivariate estimates, but no effect when the two-level analyses is implemented with standard human capital controls. If regulation is effective in restricting the supply of new entrants to some extent, then those in the occupation

are likely to work more hours. The results in Table 7 are consistent with this hypothesis, but the magnitudes are small.

Although the categorical transformation of the overall index does not show much effect on the key labor market variables of wages and hours worked, perhaps several of the individual components of the licensing index may influence wages and hours worked. The use of an examination to determine the impact of this variable on wage determination has been used in other studies (Kleiner and Kudrle, 2000; Kleiner and Krueger, 2013). Through the examination process and the establishment of higher standards, access to and supply of engineers can be reduced, and if demand remains constant, wages can increase. Moreover, the pass rate for the engineering exam also may limit the entry of new engineers and drive up wages for engineers.

In Table 8 we list the states that require a professional exam for each specific type of licensing examination. In order to become licensed, engineers usually take a fundamental or first exam, the basic step toward becoming a licensed engineer. This exam is often administered to engineers just prior to their finishing undergraduate studies. The professional exam, in contrast, covers general engineering practices and is usually given after engineers have been practicing for four or more years. It is the final stage of licensing coverage for entry into the regulated part of the occupation. Table 8 shows that Ohio and Arkansas adopted a professional exam in 2002 and 2009, respectively; they serve as basis for a difference-in-difference analysis. The difference-in-difference model is relative to Ohio and Arkansas, which were the states that changed their regulatory statutes for exams over the time period of our analysis.

In order to provide sensitivity analysis for our previous estimates and include the estimates for an additional regulatory requirement, we include whether there is a professional exam requirement to become licensed. Table 9 shows the estimates on wage and hours using

seemingly unrelated regression (SUR) methods for the influence of having a professional exam requirement as part of the licensing requirement. Since only two states changed the exam requirements during the period under study, we used this method as an additional sensitivity test of our estimates. Panel A shows the results when engineers are categorized by type of engineering field: civil, electrical, and industrial. In Panel B we estimate the model for all the engineers in our sample. Those results are consistent with the general results shown in Table 6, 7, and 8 and show only a small coefficient size for this requirement and varying levels of significance, based on the type of engineering specialty and the labor market outcome variable selected, which was hourly wages or hours worked.

In Table 10, we examine whether the lagged professional exam requirement variable may have influenced economic factors. Using the lagged professional licensing requirement and current economic data starting in 2001 through 2012, the table shows that these results are consistent in displaying a mixed to minor influence on wage determination. At least for licensing coverage, which is what our data allow us to measure, occupational licensing has a small influence on wage determination for civil engineers, but has a mixed influence on other engineering specialties. This may reflect the fact that the attainment of a license matters more with respect to wage determination, rather than the passage of a law regulating an occupation that is largely unregulated by the government (Gittleman and Kleiner, 2013). Even though H. Gregg Lewis finds that being represented by a union raises wages by about 15 percent in aggregate, for many occupations such as hospital workers and well-educated male workers, the influence of unions is either zero or even slightly negative (Lewis, 1986). Similarly, for civil engineers, who are more heavily licensed, tougher regulations may not enhance their earnings,

perhaps because unregulated workers are able to be more innovative and create new markets relative to engineers who have their work standardized by the government (Friedman, 1962).

Conclusions

Our paper presents the first comprehensive analysis of the role of occupational licensing requirements on the labor market for civil, electrical, and industrial engineers. These groups of engineers represent the largest number of engineers that are covered by occupational licensing statutes in the United States. We initially trace the historical evolution of licensing for engineers. Second, we present a theoretical rationale for the role of government in the labor market for the occupation. In the model, the government's ability to control supply through licensing restrictions and the pass rate limits the number of engineers, which may drive up wages. These results are useful for informing the empirical models for engineers.

In the empirical section, we show that licensing for these occupations has grown somewhat more rigorous during the period 2001–2012. We then estimate a panel data model for the engineers in our sample using the ACS. Our estimates show a small influence of occupational licensing on both wages and employment in a variety of specifications and sensitivity analysis tests. In the U.S. economy, if engineers achieve the goal of their professional association of more rigid requirements, and a longer time to become an engineer, the growth of regulation of the occupation may reduce customer access to engineers and slow down the ability of builders and manufacturers to use regulated engineering services. Our study provides a first look at these issues. Exploring the potential issue of selection across engineering specialties, and using more detailed analysis such as the use of discontinuities when the passage of more rigorous laws occurs, may provide more refined or precise estimates and examples of the role of regulation in

the market for engineers. Further, a more thorough analysis would include individuals who have attained a license rather than licensing coverage, and these data would allow us to obtain a better measure of the influence of occupational licensing on those who chose to get the credential to legally do certain engineering tasks.

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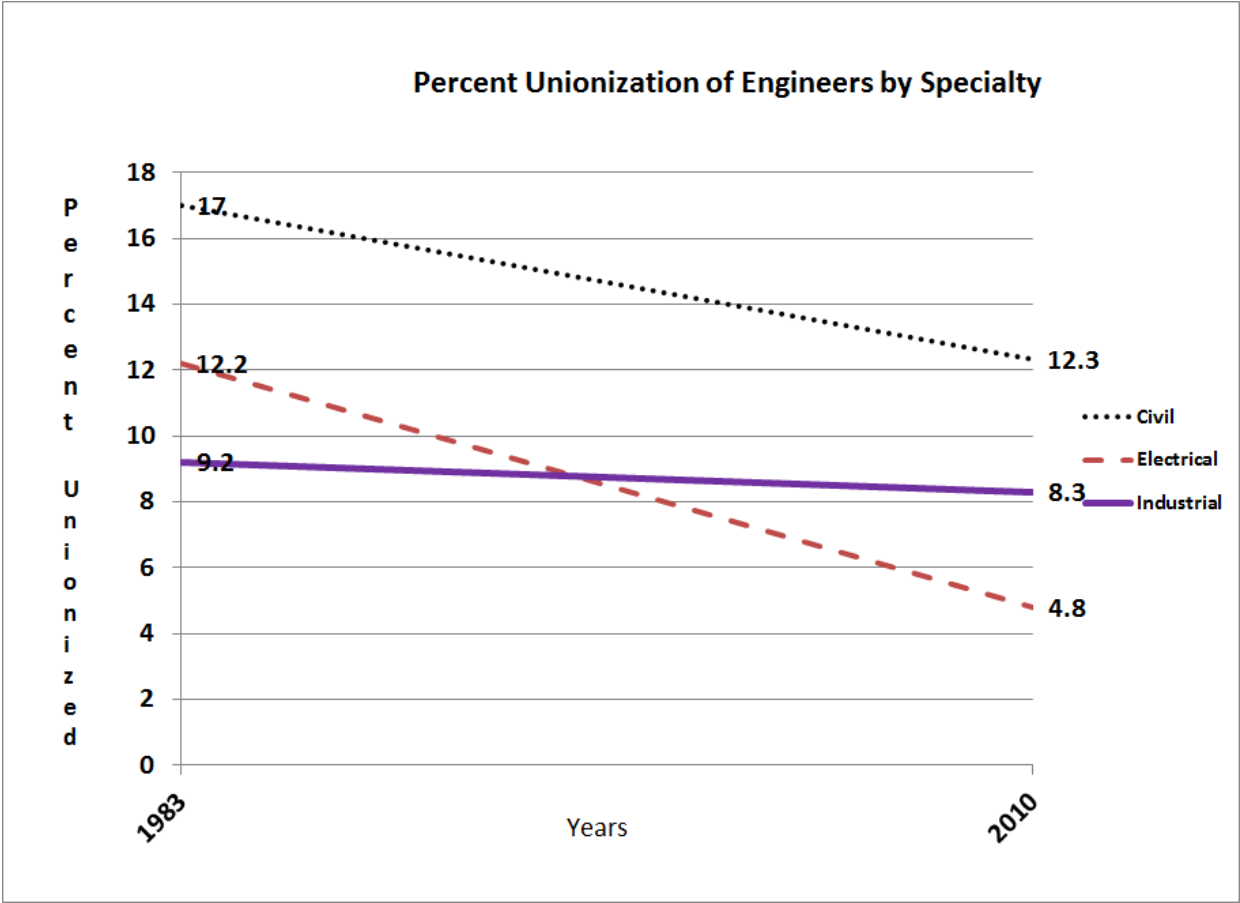
Russell, J., and W. B. Stouffer. 2003. “Change Takes Time:

The History of Licensure and Continuing Professional Competency.” Report, American Society of Civil Engineers, p.7. Available at

http://www.asce.org/uploadedFiles/Landing_Pages/Leadership_and_Management/The%20History%20of%20Licensure%20and%20Continuing%20Professional%20Competency_FINAL.pdf.

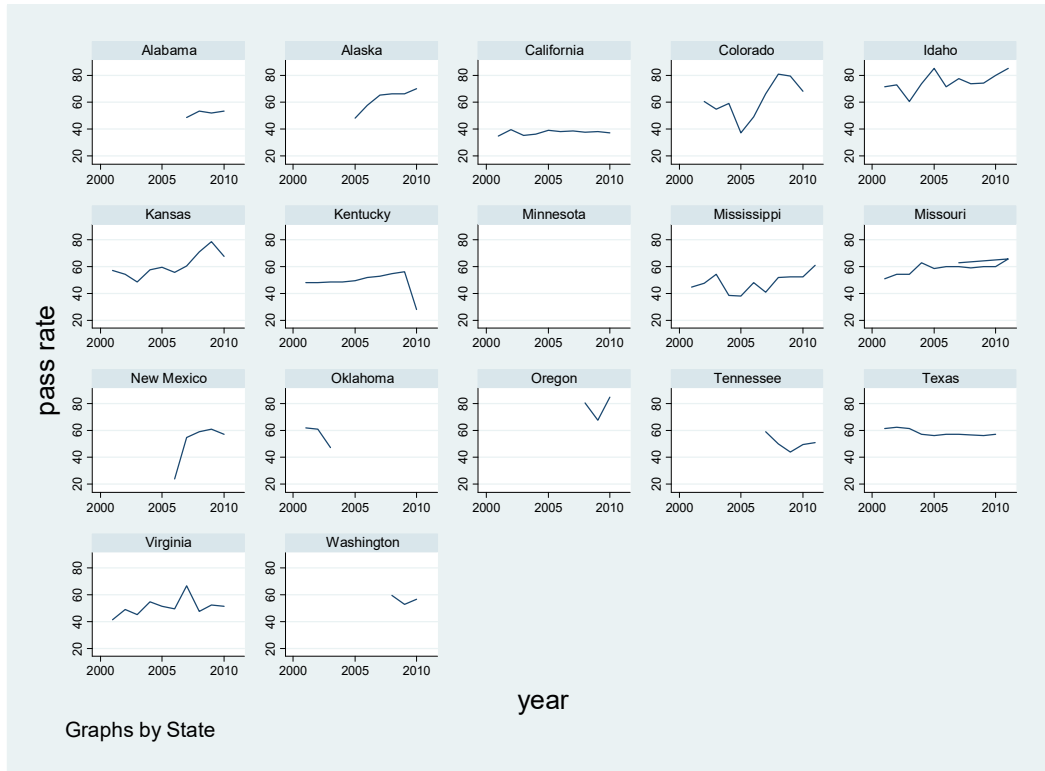
U.S. Department of Labor, Bureau of Labor Statistics. 2013. *Current Population Survey*.

Figure 1: Decline in Unionization for Civil, Electrical, and Industrial Engineers, 1983– 2010



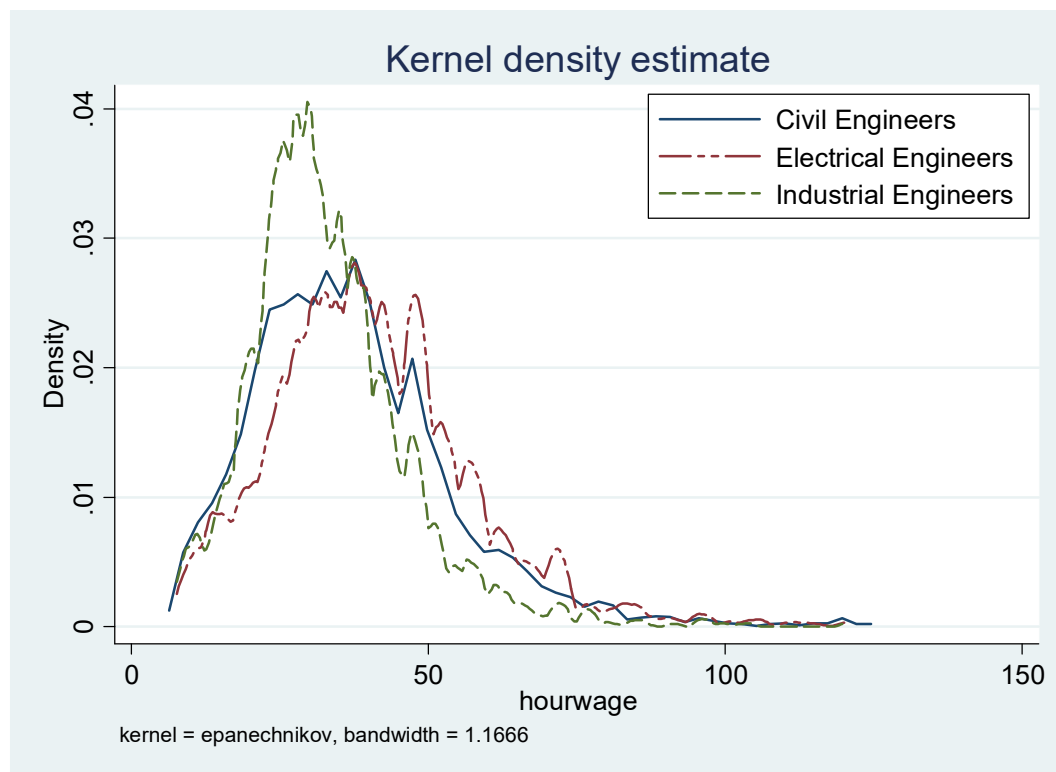
Source: *Current Population Survey*, various years calculated by the authors.

Figure 2: Engineering Exam Pass Rates by State



Sources: The pass rate data for those states that post this information was obtained from <http://ncees.org/licensing-boards/>. In addition, we contacted the state boards to obtain pass rates for engineers for others not posted.

Figure 3: Empirical Distribution of Hourly Rates for Three Types of Engineers, 2009



Source: *Current Population Survey*, various years.

Note: Sample includes those engineers who make above the minimum wage and excludes those with hourly wages greater than the top 1 percent.

Table 1: Percentage of Engineers Licensed by Specialty, 1995* and 2012**

Engineering Discipline	Percentage Licensed 1995	Percentage Licensed 2012
Civil	44	31
Electrical	9	9
Industrial	8	9

*Source: Paul Taylor, *NCEES Licensure Bulletin*, December 1995.

** Survey of Income and Program Participation, 2013

Table 2: Key Elements in Development of the Licensing Index for Engineers

Major Components	Definition
Education requirement	3 if minimum level of education required to be licensed is bachelor's degree; 2 if it is associate's degree; 1 if board decides; otherwise 0
Experience requirement	3 if minimum level of education required to be licensed is 8 years; 2 if it is 4 years; 1 if it is 2 years; 0 if no requirement
Professional exam requirement	1 if professional exam is required to be licensed; otherwise 0
Fundamental exam requirement	1 if fundamental engineering exam is required; otherwise 0
Interim exam requirement	1 if exam required for interim permit; otherwise 0
Continuing education requirement	1 if state has any requirement for continuing education; otherwise 0
Specific exam requirement	1 if specific additional exam is required for engineering discipline; otherwise 0

Source: Developed by the authors.

Table 3: Growth of Occupational Licensing Intensity over Time

Year	No. of state	Mean	Std. Dev.	Min	Max
1995	51	6.94	2.04	0.00	9.00
1996	51	6.86	2.03	0.00	9.00
1997	51	6.89	1.86	0.00	9.00
1998	51	7.08	1.71	0.00	9.00
1999	51	7.08	1.71	0.00	9.00
2000	51	7.06	1.70	0.00	9.00
2001	51	7.06	1.70	0.00	9.00
2002	51	7.06	1.70	0.00	9.00
2003	51	7.06	1.70	0.00	9.00
2004	51	7.08	1.72	0.00	9.00
2005	51	7.08	1.72	0.00	9.00
2006	51	7.08	1.72	0.00	9.00
2007	51	7.08	1.72	1.00	9.00
2008	51	7.08	1.72	1.00	9.00
2009	51	7.08	1.72	1.00	9.00
2010	51	7.25	1.59	1.00	9.00
2011	51	7.25	1.59	1.00	9.00
2012	51	7.25	1.58	1.00	9.00

Note: Index is the summated rating value of the key provisions for licensing engineers as noted in Table 2 tabulated by the authors.

Table 4: Regulation Rankings of Top and Bottom States by Restrictiveness of Licensing, 2009

Top States		Bottom States	
	Index		Index
Pennsylvania	9	Virginia	1
Georgia	9	Minnesota	3
Texas	9	South Dakota	4
Illinois	9	DC	5
Arizona	9	Delaware	5
Colorado	9	Connecticut	5

Table 5: Key Variables for Engineers in the ACS, 2001–2012

	Civil Engineers		Electrical Engineers		Industrial Engineers	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Age	43.05	11.27	43.48	10.65	43.76	10.83
Schooling (in Year)	16.00	1.67	16.21	1.66	15.70	1.66
Gender (Male:1; Female:0)	0.74	0.44	0.91	0.28	0.81	0.39
Married (Married:1; Not Married:0)	0.73	0.45	0.76	0.43	0.74	0.44
Experience (in Year)	21.05	11.40	21.28	10.89	22.06	11.11
Experience-Squared	572.88	495.33	571.25	473.94	610.37	492.57
White (White:1; Others:0)	0.84	0.36	0.79	0.41	0.87	0.34
Black (Black:1; Others:0)	0.05	0.22	0.04	0.20	0.04	0.19
Citizen (U.S. Citizen:1; Others:0)	0.95	0.21	0.91	0.29	0.94	0.23
Work for For-Profit (Yes:1; No:0)	0.70	0.64	0.88	0.32	0.93	0.26
Work for Not-for-Profit (Yes:1; No:0)	0.04	0.49	0.02	0.14	0.01	0.11
Work for Government (Yes:1; No:0)	0.24	0.62	0.09	0.28	0.05	0.22
Self-employment (Yes:1; No:0)	0.05	0.49	0.01	0.12	0.01	0.08
Hourly Earnings (in 2009 dollars)	34.61	21.20	37.47	18.41	30.35	14.72

Source: American Community Survey.

Table 6: Influence of Statutory Rank Index on Wage Determination: High Relative to Medium and Low

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	One- level Analysis	Two- level Analysis	One- level Analysis	Two- level Analysis	One- level Analysis	Two- level Analysis	One- level Analysis	Two- level Analysis
Sample	All	All	Civil	Civil	Electrical	Electrical	Industrial	Industrial
Highest rank	0.024*** (0.000)	0.007 (0.016)	0.013*** (0.001)	-0.008 (0.023)	0.023*** (0.001)	0.026 (0.028)	0.042*** (0.001)	-0.014 (0.034)
Observations	7,231,650	612	3,404,866	612	2,300,115	605	1,526,669	580
R-squared	0.000	0.852	0.000	0.715	0.000	0.706	0.000	0.580
Basic control	NO	YES	NO	YES	NO	YES	NO	YES
Year fixed	NO	YES	NO	YES	NO	YES	NO	YES
State fixed	NO	YES	NO	YES	NO	YES	NO	YES

Note: Estimated with age, schooling in years, gender, marital status, experience, experience-squared, race, U.S. citizenship, for profit sector, and self-employment. Two-stage regressions are weighted by the number of engineers. The second-stage estimates are aggregate state-level estimates of hours worked calculated from the predicted hours worked individual model, which are then aggregated to the state level. The ACS sample uses individuals who earn less than \$250 per hour and who are college graduates. Standard errors are in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 7: Influence of Statutory Rank Index on Hours Worked: High Relative to Medium and Low

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	One-level	Two-level	One-level	Two-level	One-level	Two-level	One-level	Two-level
Sample	Analysis All	Analysis All	Analysis Civil	Analysis Civil	Analysis Electrical	Analysis Electrical	Analysis Industrial	Analysis Industrial
Highest rank	0.010*** (0.000)	0.009 (0.006)	0.010*** (0.000)	0.010 (0.008)	0.015*** (0.000)	0.012 (0.009)	0.005*** (0.000)	0.008 (0.011)
Observations	7,231,650	612	3,404,866	612	2,300,115	605	1,526,669	580
R-squared	0.001	0.335	0.001	0.202	0.002	0.216	0.000	0.196
Basic control	NO	YES	NO	YES	NO	YES	NO	YES
Year fixed	NO	YES	NO	YES	NO	YES	NO	YES
State fixed	NO	YES	NO	YES	NO	YES	NO	YES

Note: Estimated with age, schooling in years, gender, marital status, experience, experience-squared, race, U.S. citizenship, for profit sector, and self-employment. Two-stage regressions are weighted by the number of engineers. The second-stage estimates are aggregate state-level estimates of hours worked calculated from the predicted hours worked individual model, which are then aggregated to the state level. The ACS sample uses individuals who earn less than \$250 per hour and who are college graduates. Standard errors are in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 8: State Professional Exam Requirements for Licensure of Engineers, 2001–2012

Professional exam required	No professional exam required	Changer (year of change)
Alabama		Ohio (2002)
Alaska		
Arizona		Arkansas (2009)
California	Hawaii	
Colorado	Missouri	
Connecticut	New Hampshire	
Delaware	New Jersey	
District of Columbia	New Mexico	
Florida	Oregon	
Georgia	South Dakota	
Idaho	Utah	
Illinois	Virginia	
Indiana	Washington	
Iowa	Wisconsin	
Kansas	Wyoming	
Kentucky		
Louisiana		
Maine		
Maryland		
Massachusetts		
Michigan		
Minnesota		
Mississippi		
Montana		
Nebraska		
Nevada		
New York		
North Carolina		
North Dakota		
Oklahoma		
Pennsylvania		
Rhode Island		
South Carolina		
Tennessee		
Texas		
Vermont		
West Virginia		

Table 9

Panel A: Effect of a Professional Exam on Wage and Hours Worked Using Seemingly Unrelated Regressions (SUR)

Sample	Civil Engineers				Electrical Engineers				Industrial Engineers				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	
	One Step		Two step		One Step		Two step		One Step		Two step		
VARIABLES	Log of wage	Log of Hours worked	Log of wage	Log of Hours worked	Log of wage	Log of Hours worked	Log of wage	Log of Hours worked	Log of wage	Log of Hours worked	Log of wage	Hours worked	
index_pe	index_pe	-0.002*** (0.001)	0.003*** (0.000)	-0.146*** (0.048)	-0.057*** (0.017)	0.003*** (0.001)	0.006*** (0.000)	0.042 (0.060)	0.012 (0.020)	-0.025*** (0.001)	-0.001** (0.000)	-0.143** (0.071)	-0.002 (0.023)
Constant		3.437*** (0.001)	3.756*** (0.000)	3.637*** (0.056)	3.796*** (0.020)	3.520*** (0.001)	3.755*** (0.000)	3.537*** (0.068)	3.730*** (0.023)	3.351*** (0.001)	3.781*** (0.000)	3.551*** (0.081)	3.802*** (0.027)
Observations	Observations	3,404,866	3,404,866	612	612	2,300,115	2,300,115	605	605	1,526,669	1,526,669	580	580
R-squared	R-squared	0.000	0.000	0.719	0.219	0.000	0.000	0.706	0.209	0.000	0.000	0.583	0.168
Basic control	Basic control	NO	NO	YES	YES	NO	NO	YES	YES	NO	NO	YES	YES
Year fixed	Year fixed	NO	NO	YES	YES	NO	NO	YES	YES	NO	NO	YES	YES
State fixed	State fixed	NO	NO	YES	YES	NO	NO	YES	YES	NO	NO	YES	YES

Panel B: Effect on Wage Using SUR for All Engineers

	(1)	(2)	(3)	(4)
ANALYSIS	One Step		Two Step	
VARIABLES	Log of wage	Log of Hours work	Log of wage	Log of Hours work
index_pe	-0.006*** (0.000)	0.004*** (0.000)	-0.107*** (0.034)	-0.022* (0.012)
Constant	3.446*** (0.000)	3.760*** (0.000)	3.571*** (0.039)	3.775*** (0.013)
Observations	7,231,650	7,231,650	612	612
R-squared	0.000	0.000	0.854	0.303
Basic control	NO	NO	YES	YES
Year fixed	NO	NO	YES	YES
State fixed	NO	NO	YES	YES

Note: Panels A and B were estimated with age, schooling in years, gender, marital status, experience, experience-squared, race, U.S. citizenship, for profit sector, and self-employment. Two-stage regressions are weighted by the number of engineers. The second-stage estimates are aggregate state-level estimates of hours worked calculated from the predicted hours worked individual model, which are then aggregated to the state level. The ACS sample uses individuals who earn less than \$250 per hour and who are college graduates. Standard errors are in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 10: Influence of Lagged Professional Exam on Wages and Hours Worked, 2001–2012

Sample	All Engineers		Civil Engineers		Electrical Engineers		Industrial Engineers	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Analysis	One- step	Two- step	One- step	Two- step	One- step	Two- step	One- step	Two- step
Panel A: Dependent is log of hourly wage								
Lag professional exam	0.000 (0.000)	-0.076** (0.030)	0.003*** (0.001)	-0.066 (0.043)	0.008*** (0.001)	-0.004 (0.053)	-0.016*** (0.001)	-0.128** (0.063)
Constant	3.440*** (0.000)	3.564*** (0.036)	3.433*** (0.001)	3.558*** (0.052)	3.515*** (0.001)	3.589*** (0.064)	3.343*** (0.001)	3.493*** (0.076)
Observations	7,231,650	612	3,404,866	612	2,300,115	605	1,526,669	580
R-squared	0.000	0.853	0.000	0.716	0.000	0.706	0.000	0.583
Panel B: Dependent is log hours worked								
Lag professional exam	0.004*** (0.000)	-0.011 (0.010)	0.003*** (0.000)	-0.037** (0.016)	0.007*** (0.000)	0.024 (0.018)	-0.001*** (0.000)	-0.010 (0.021)
Constant	3.761*** (0.000)	3.763*** (0.012)	3.756*** (0.000)	3.772*** (0.019)	3.754*** (0.000)	3.717*** (0.021)	3.782*** (0.000)	3.807*** (0.025)
Observations	7,231,650	612	3,404,866	612	2,300,115	605	1,526,669	580
R-squared	0.000	0.300	0.000	0.213	0.000	0.211	0.000	0.168
Basic control	NO	YES	NO	YES	NO	YES	NO	YES
Year fixed	NO	YES	NO	YES	NO	YES	NO	YES
State fixed	NO	YES	NO	YES	NO	YES	NO	YES

Note: Estimated with age, schooling in years, gender, marital status, experience, experience-squared, race, U.S. citizenship, for profit sector, and self-employment. Two-stage regressions are weighted by the number of engineers. The second-stage estimates are aggregate state-level estimates of hours worked calculated from the predicted hours worked individual model, which are then aggregated to the state level. The ACS sample uses individuals who earn less than \$250 per hour and who are college graduates. Standard errors are in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Appendices

Table A1: Influence of Professional Exams (PE) and Pass Rates on Wage Determination of Engineers

Sample	All Engineers		Civil Engineers		Electrical Engineers		Industrial Engineers	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ANALYSIS VARIABLES	One- Step Log of wage	Two- Step Log of wage	One- Step Log of wage	Two- Step Log of wage	One- Step Log of wage	Two- Step Log of wage	One- Step Log of wage	Two- Step Log of wage
PE*Pass rate	-0.008*** (0.000)	0.000 (0.001)	-0.005*** (0.000)	0.001 (0.002)	-0.013*** (0.000)	0.000 (0.002)	-0.006*** (0.000)	0.000 (0.001)
PE	0.452*** (0.005)	-0.040 (0.048)	0.251*** (0.007)	-0.044 (0.092)	0.744*** (0.008)	-0.027 (0.096)	0.320*** (0.011)	-0.066 (0.074)
Pass rate	0.004*** (0.000)	-0.001 (0.001)	0.002*** (0.000)	-0.001 (0.001)	0.008*** (0.000)	-0.000 (0.001)	0.003*** (0.000)	-0.000 (0.001)
Constant	3.210*** (0.005)	3.345*** (0.040)	3.340*** (0.007)	3.307*** (0.077)	3.051*** (0.008)	3.418*** (0.081)	3.156*** (0.011)	3.295*** (0.062)
Observations	2,195,841	123	1,007,204	123	775,218	123	413,419	122
R-squared	0.009	0.976	0.004	0.918	0.019	0.924	0.004	0.940
Basic control	NO	YES	NO	YES	NO	YES	NO	YES
Year fixed	NO	YES	NO	YES	NO	YES	NO	YES
State fixed	NO	YES	NO	YES	NO	YES	NO	YES

Note: Estimated with age, schooling in years, gender, marital status, experience, experience-squared, race, U.S. citizenship, for profit sector, and self-employment. Two-stage regressions are weighted by the number of engineers. The second-stage estimates are aggregate state-level estimates of hours worked calculated from the predicted hours worked individual model, which are then aggregated to the state level. The ACS sample uses individuals who earn less than \$250 per hour and who are college graduates. Standard errors are in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table A2: Effect of Professional Exams (PE) and Pass Rates on Hours Worked

Sample	All Engineers		Civil Engineers		Electrical Engineers		Industrial Engineer	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ANALYSIS	One- Step	Two- Step	One- Step	Two- Step	One- Step	Two- Step	One- Step	Two- Step
VARIABLES	Hours Worked	Hours Worked	Hours Worked	Hours Worked	Hours Worked	Hours Worked	Hours Worked	Hours Worked
PE*Pass rate	0.000*** (0.000)	-0.000 (0.000)	0.001*** (0.000)	0.000 (0.000)	-0.000*** (0.000)	-0.000 (0.000)	0.001*** (0.000)	-0.000 (0.000)
PE	-0.018*** (0.002)	0.016** (0.007)	-0.061*** (0.002)	0.006 (0.010)	0.041*** (0.002)	0.005 (0.015)	-0.033*** (0.003)	0.023 (0.014)
Pass rate	0.000*** (0.000)	0.000 (0.000)	-0.000*** (0.000)	0.000 (0.000)	0.001*** (0.000)	0.000* (0.000)	0.000* (0.000)	-0.000 (0.000)
Constant	3.750*** (0.001)	3.751*** (0.006)	3.773*** (0.002)	3.742*** (0.008)	3.709*** (0.002)	3.752*** (0.013)	3.775*** (0.003)	3.779*** (0.012)
Observations	2,195,841	123	1,007,204	123	775,218	123	413,419	122
R-squared	0.002	0.950	0.004	0.952	0.003	0.882	0.003	0.915
Basic control	NO	YES	NO	YES	NO	YES	NO	YES
Year fixed	NO	YES	NO	YES	NO	YES	NO	YES
State fixed	NO	YES	NO	YES	NO	YES	NO	YES

Note: Estimated with age, schooling in years, gender, marital status, experience, experience-squared, race, U.S. citizenship, for profit sector, and self-employment. Two-stage regressions are weighted by the number of engineers. The second-stage estimates are aggregate state-level estimates of hours worked calculated from the predicted hours worked individual model, which are then aggregated to the state level. The ACS sample uses individuals who earn less than \$250 per hour and who are college graduates. Standard errors are in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table A2: Effect of Pass Rates on Hours Worked (cont.)

Sample	All Engineers		Civil Engineers		Electrical Engineers		Industrial Engineers	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ANALYSIS	One- Step	Two- Step	One- Step	Two- Step	One- Step	Two- Step	One- Step	Two- Step
VARIABLES	Hours Worked	Hours Worked	Hours Worked	Hours Worked	Hours Worked	Hours Worked	Hours Worked	Hours Worked
PE	-0.055 (0.038)	0.116 (0.096)	0.020 (0.054)	0.224 (0.158)	-0.737*** (0.080)	-0.690*** (0.159)	0.592*** (0.075)	0.496*** (0.151)
Pass rate	-0.006*** (0.001)	-0.006*** (0.002)	0.013*** (0.001)	0.014*** (0.003)	-0.017*** (0.001)	-0.018*** (0.003)	-0.037*** (0.002)	-0.039*** (0.003)
Observations	2,601,433	123	1,175,107	123	908,387	123	517,939	122
R-squared	0.038	0.962	0.051	0.946	0.045	0.953	0.038	0.967
Basic control	YES	YES	YES	YES	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES	YES	YES	YES	YES
State fixed	YES	YES	YES	YES	YES	YES	YES	YES

Note: Basic controls include age, schooling in years, gender, marital status, experience, experience-squared, race, U.S. citizenship, for profit sector, and self-employment. Two-stage regressions are weighted by the number of engineers. The second-stage estimates are aggregate state-level estimates of hours worked calculated from the predicted hours worked of individuals, which are then aggregated to the state level. Standard errors are in parentheses.

*** p<0.01, ** p<0.05, * p<0.1