Dropouts Need Not Apply? The Minimum Wage and Skill Upgrading

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Abstract:

We explore whether minimum wage increases result in substitution from lower-skilled to slightly higher-skilled labor. Using 2011-2016 American Community Survey data (ACS), we show that workers employed in low-wage occupations are older and more likely to have a high school diploma following recent statutory minimum wage increases. To better understand the role of firms, we examine the Burning Glass vacancy data. We find increases in a high school diploma requirement following minimum wage hikes, consistent with our ACS evidence on stocks of employed workers. We see substantial adjustments to requirements both within and across firms.

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1 Introduction

The minimum wage remains a hotly debated topic among economists, policymakers, and the public. Most research focuses on the equilibrium employment effects of increases in wage floors, though there is recognition that other margins of adjustment may play a role.[1] One important avenue by which firms may adjust in the face of minimum wage increases is through substitution towards higher-skilled labor. If the minimum wage exceeds the value of a worker's output, a firm can potentially find a replacement worker whose productivity meets or exceeds the floor. This phenomenon of "labor-labor substitution" may have important distributional consequences, even when effects on aggregate employment are modest.

To the extent that jobs shift towards higher skilled workers, those who are replaced (or never hired) may be disproportionately from already disadvantaged groups. Broadly speaking, such groups may include the young, less-educated, uncredentialed, and those living in low-income households. Evidence on transitions from minimum wage jobs to higher earnings (Smith and Vavrichek, 1992; Even and Macpherson, 2010) and on the returns to early career labor-market experience (Lemieux, 2006; Kahn, 2010) suggest that increases in the difficulty of finding a first job can have long-run impacts (Neumark and Nizalova, 2007).

We examine labor-labor substitution in response to minimum wage increases through

[1]See Clemens et al. (2018), Gooptu and Simon (2019), and Simon and Kaestner (2004) on non-wage compensation; Hamermesh (1996), Aaronson and Phelan (2019), Lordan and Neumark (2018), Chen (2018); Hirsch et al. (2015) on capital-labor substitution; Basker et al. (2017) on customer-labor substitution; Adams et al. (2018) on supply-side responses; Aaronson (2001), Aaronson et al. (2008), Harasztosi and Lindner (2019) for evidence of incidence on consumers; Harasztosi and Lindner (2019), Draca et al. (2011),and Bell and Machin (2018) for evidence of incidence on firm owners; Coviello et al. (2018) and Ku (Forthcoming) on incidence through increases in worker effort. Although not directly related to the incidence of the minimum wage, the analyses of Altonji and Paxson (1988, 1990) point to an additional margin of interest, namely that firms might offer workers a rigid menu of hours-wage combinations. A minimum wage increase may render some of these combinations (flexible hours with low throughput and hence a low wage, for example) illegal. Incidence may thus be borne in part by the worker through changes in schedule-related amenities, as illustrated by Clemens and Strain (Forthcoming) using a simple model.

two analyses. First, using American Community Survey (ACS) data, we document that employment shares of young adults and those without a high school degree fall in low-wage occupations after minimum wage increases. Our difference-in-differences identification strategy exploits the many statutory minimum wage increases that occurred from 2014-2016. Our results are robust to the inclusion of extensive controls, including state-time varying labor market conditions as well as occupation-by-time and occupation-by-state fixed effects. We categorize individuals who are more exposed to minimum wage increases based on the pay distribution of their occupation (Clemens et al., 2018). We find that effects are concentrated among individuals employed in low-wage occupations. Following recent statutory minimum wage increases, which averaged around $1.70 over the course of our sample, individuals in these groups are, on average, a quarter of a year older and 4 to 5 percent less likely to be a young adult (age 16 to 21) or to lack a high school degree. We see no impacts on employment shares for other demographic groups, including those defined by race, gender, and country of birth.

To better understand the role that firms play in this "upskilling" process, we turn to data from Burning Glass Technologies (BGT) for the 2011-2016 period. The BGT data contain the near universe of online job postings in the United States. We show that the prevalence of requirements for a high school diploma increase following minimum wage hikes. The effect is concentrated among postings for low-wage occupations, where the diploma requirement increases by about 10 percent. We find no effects for higher levels of education, like college degrees, that should be unaffected by minimum wage increases. We also find little impact on experience and other skill requirements.

Previous research has explored employment impacts of the minimum wage on multiple population subgroups, with a goal of understanding whether losses for one group are offset by gains for others.[2] Recent work highlights that more detailed data may be

[2]This discussion goes back at least as far as Smith (1907). Early 20th century empirical work found

required to estimate labor-labor substitution with precision, since coarse demographic groupings do a highly imperfect job of tracking minimum wage workers (Clemens and Wither, 2019; Horton, 2017).

We contribute to this literature by going beyond employment outcomes to provide an in-depth look at the firm-level response for labor. Our analysis of vacancy postings allows us to examine the flow of jobs rather than the stock, which can be slow to reflect the totality of a minimum wage change's effects (Meer and West, 2016). Research on recent minimum wage changes has found evidence that firms adjust their hiring to a far greater degree than their firing (Jardim et al., 2018; Gopalan et al., Forthcoming). Consequently, flows of job vacancy postings can provide a valuable lens for examining firm responses to minimum wage increases.

In general, it is difficult to know whether changes in equilibrium employment stocks are driven by supply-side responses, the composition of firms, within-firm demand, or by changes in the nature of the jobs within each occupation code. The BGT data allow us to examine effects both across and within firms. We find that changes in high school diploma requirements occur along both margins. That is, the composition of postings shifts towards firms that always tended to require more credentials, but upskilling effects are also present within firms.[3] Within-firm responses thus complement the margins of firm-level exit and entry, which have been emphasized in recent work by Sorkin (2015) and Aaronson et al. (2018).

This paper proceeds as follows. Section 2 provides a discussion of the theory underlying potential effects of interest. Section 3 describes the minimum wage changes we

that the introduction of minimum wages for experienced female workers led to "the dismissal of particular women rather than others, because they... must be paid a higher wage if retained" (Obenauer and von der Nienburg, 1915). More recently, Neumark and Wascher (1996), Ahn et al. (2011), and Dube et al. (2016) focus on teenagers and Luttmer (2007) examines effects by skill groups.

[3]Our within-firm analysis expands on the existing body of research that analyzes in-depth surveys on small groups and/or administrative data on individual firms (Card and Krueger, 1995; Fairris and Bujanda, 2008; Hirsch et al., 2015; Giuliano, 2013).

analyze and our approach to estimating their effects. Section 4 presents our analysis of worker skills using ACS data and section 5 presents our analysis of skill requirements using BGT data. Section 6 concludes.

2 Conceptual Framework

This section illustrates the channels through which a minimum wage increase can generate labor-labor substitution, i.e., an increase in the skill level of workers and the skill requirements in job postings in low-wage occupations. Consider a set of firms that produce in a low-skilled market (e.g., retail or fast food). At baseline, firms may differ with respect to the skill composition of their workforces, such that some firms have workers with very low marginal products while others do not. That is, even though all workers in this market are relatively unskilled, the latter firms may be producing with a combination of low- and slightly higher-skilled workers.

We say that a minimum wage "binds" for a firm if it falls above the wage that firm pays out to at least some workers. When the government introduces or raises the minimum wage, it will be more likely to bind for firms that employ the least-skilled workers. The minimum wage's effects depend on the degree to which it binds as well as whether the labor market is perfectly or imperfectly competitive. A barely-binding minimum wage may trivially affect employment. In a classic monopsony model, the minimum wage's initial bite may even generate an increase in the least-skilled workers' employment. As the minimum wage binds further, firms with low-skilled workers may exit or contract, while firms with higher skilled workers may remain similar in scale. They may even expand if their competitors contract due to the binding cost shock. This "between-firm labor substitution" pushes towards a decline in the relative employment rates of the least skilled.

Further, firms with low-skilled workers may try to increase productivity through several channels. They may increase effort requirements for existing workers, they may replace some of their existing workforce with higher skilled workers, and they may substitute away from labor and towards capital. The second margin, namely "within-firm labor substitution," can occur whenever high- and low-skilled workers are substitutes in production.[4] The array of firms' potential responses can generate a relationship between the skill of employed workers and the level of the minimum wage that is highly non-linear. A small increase in the minimum wage may lead firms to demand greater effort from existing workers, for example, while a moderate increase might lead to substitution towards higher skilled workers and a large increase might lead firms to replace jobs with capital or scale back on operations.

A simple task framework provides an illustration. In the retail context, a task could be an order processed at a cash register. Skill in this context could be synonymous with speed, or the ability to show up on time and take fewer breaks. That is, higher-skilled workers are more productive in terms of the orders they process per hour. When facing a binding minimum wage, a firm might try to increase productivity by replacing their slowest workers with faster, higher-skilled workers. Firms might also encourage their existing workforce to exert more effort so as to process orders faster. Finally, firms might replace labor with capital by transitioning to self-serve kiosks.

The extent to which these effects occur depends on the degree of substitutability across worker skill and the elasticity of labor supply. Labor supply may shift in response to minimum wage increases. A larger pool of workers may make themselves available, either because the minimum wage has made the labor market more attractive, or because some firms shut down, leaving their workers to return to the job market. Supply-side

[4]For instance, standard Cobb-Douglas and Constant Elasticity of Substitution production functions can generate this type of response, with magnitudes depending on either type of production function's parameters. See Hamermesh and Grant (1979).

effects may either dampen or magnify the more direct demand-side effects of a minimum wage increase on the skill mix of those who are employed.[5]

What do these forces imply for the skill requirements observed in vacancy postings? Vacancy postings may reflect both demand- and supply-side factors. Demand-side forces are the most direct: when firms seek higher-skilled workers, the requirements in their vacancy postings should rise. Supply-side forces may also be relevant, as posted skill requirements serve a pre-screening function. The supply-side forces discussed above might result in an increase in job applicants. In response, firms may increase their posted skill requirements even if they do not desire to alter the skill mix of their workforce.[6] The posted requirement would then serve the function of deterring an influx of applications that would ultimately be unsuccessful. Notably, this provides a mechanism through which the minimum wage can affect vacancy postings at firms that do not actually employ minimum wage workers.

In summary, this section illustrates two primary channels that could increase the skill level of workers employed in minimum wage jobs: shifts in employment between firms and the substitution of higher-skilled workers for the least-skilled workers within firms. Qualitatively, we note that the relationship between the skill mix of workers and the size of the minimum wage change could be non-linear. Finally, while job posting requirements should tend to mirror employer demand for skill, they may also adapt to the supply side of the market as a means of signalling the firm's needs to an evolving pool of potential applicants.

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[5]Adams et al. (2018) show that the unemployed increase time spent searching for work following a minimum wage hike. Phelan (2019) shows that a minimum wage increase can alter the mix of wages and amenities for a job such that some workers who were initially in modest-wage jobs now prefer jobs that were previously low-wage jobs.

[6]Kuhn and Shen 2013 discuss conditions when skill requirements in vacancy postings should increase, one of which being an increase in the total number of applicants.

3 Empirical Approach

We examine data from 2011-2016, which has several benefits. First, it is a time period during which there is substantial state variation in minimum wage policies. Second, it falls cleanly after the Great Recession and the federal minimum wage increases of 2007 to 2009. Finally, our analysis period allows us to analyze ACS employment data and vacancy posting data from Burning Glass Technologies in parallel.

In section 3.1, we describe variation in state minimum wage policies over the time period we analyze. In section 3.2, we describe our approach to identifying minimum wage occupations. In section 3.3, we present our estimation framework.

3.1 Minimum Wage Variation

As in Clemens et al. (2018), we focus our attention on state-level minimum wage changes that occur after 2011.[7] There was a lull in minimum wage legislation between the end of the Great Recession and December 2013 (Clemens and Strain, 2017). Since January 2014, a substantial number of states have increased their minimum wages through new legislation. Data from 2011-2013 thus provide a base period after which states' minimum wage policies diverged substantially.

Table 1 summarizes minimum wage changes by state, listing the total minimum wage change across our analysis period for each state that enacted a change through new legislation. We also list the number of years in which a change occurred and the year of the first change. For example, Alaska saw a total increase of $2.00 over the period 2011-2016 that occurred through two consecutive $1 increases in January 2015 and January 2016. Notably, all states in the table had multiple increases over our analysis period. Because the second (and in some cases third) increase was typically enacted through

[7]The sources underlying our minimum wage series include Meer and West (2016), Vaghul and Zipperer (2016) and Clemens and Strain (2017).

the same piece of legislation as the first, it would generally have been forecastable by firms. This leads us to pursue a difference-in-differences analysis centered on the first minimum wage change for each state. We also explore the timing of any impacts we observe through dynamic event study analyses.

In addition to the states listed in table 1, there are 8 states that had inflation indexing provisions over this time period. In a typical year, these states enact forecastable minimum wage increases on the order of $0.15 to $0.20.[8] Because the minimum wage increases in these states are both small and forecastable, they are not our primary focus.[9] We report separate effects for inflation indexers in several appendix tables.

3.2 Occupation Groups

Our analysis focuses on groups of occupations that are most likely to be impacted by minimum wage legislation. Our occupation-based approach follows Clemens et al. (2018), and is well-suited for investigating the phenomenon of labor-labor substitution.[10] Using the 2006 wave of the Occupational Employment Statistics (OES) data, we classify occupations based on the 10th percentile of their occupation-specific wage distributions.[11] We choose 2006 because it predates both the minimum wage increases we study and the Great Recession. Our analysis focuses on the bottom 10 percent of occupations (as sorted based on the 10th percentile of each occupation's 2006 wage distribution). These occupations are most likely to be mechanically impacted by minimum wage law,

[8]These states are Arizona, Colorado, Florida, Missouri, Montana, Ohio, Oregon, and Washington. Rhode Island and Vermont switched from indexed to statutory increases over the time period we study; we focus on only the statutory increases for these states.

[9]Increases of this sort are of little interest in part because it is already known that they have very modest effects at the time each increase is implemented.

[10]It is also a necessity for our analysis of the Burning Glass data, which contain sparse data on pay and no data on demographics.

[11]We use four-digit SOC occupations, balancing the need for granularity against sample size constraints.

as they are particularly low-earning.[12] We henceforth refer to the lowest decile as "low-wage occupations." For most of our analysis, we group higher-paying occupations into "modest wage" (deciles 2-4), "medium wage" (deciles 5-7) and "high wage" (deciles 8-10) categories, though we also explore finer groupings.

Table 2 lists the low-wage occupations in order of their 10th percentile wage in 2006. The low-wage occupations include those typically associated with minimum wage jobs, such as waiters, retail clerks, and cleaners. The table illustrates how the recent statutory minimum wage increases compare to prevailing wages. For each state-occupation cell, we calculate the gap between wages in the 2013 OES wave and the state minimum wage in 2016.[13] We summarize this gap for the 10th, 25th, and 50th percentiles of wages. We average across states using OES employment weights and imputing zeros for negative gaps. This gives us the amount that, for example, the 10th percentile wage would have needed to increase in a given occupation to be in mechanical compliance with the eventual minimum wage, averaged across all states with statutory increases. Note that these estimates do not take into account any nominal wage growth that might otherwise have occurred over our analysis period. Our calculations simply illustrate the occupations for which we should expect to see the largest mechanical wage increases due to compliance with new minimum wage law.

In panel A, we estimate that low-wage occupations should see sizable wage increases at the lower half of their wage distribution. For food and beverage serving workers (SOC code 3530), for example, the 10th percentile wage would need to rise by an average of $1.27 to be in compliance with the average increase. This is three-quarters of the actual minimum wage increase seen over this time period: $1.68 (the average among statutory

[12]The categories we describe here are slightly different than in Clemens et al. (2018) to better align with categories found in the BGT data. See below for more discussion and robustness to other definitions.

[13]OES data are three-year rolling averages, so the 2013 wave corresponds to the 2011-2013 "pre" period in our data before any statutory legislation.

increasers). Workers in some locations were earning slightly above the prevailing minimum wage in 2013, such that the effective wage increase imposed by the minimum wage hikes was lower than the full increase. At the 25th percentile, wages in this occupation would only have needed to increase by $0.87; at the median the gap is just $0.30. Across low-wage occupations, the average increases required at the 10th percentile range from $0.38 to $1.34, while expected increases at the median are almost always close to zero. A portion of our analysis focuses on the three lowest-paying occupations (food and beverage serving, other food preparation and serving, and entertainment attendants) because these occupations exhibit substantial exposure to the minimum wage across a larger range of their occupation-specific wage distributions.[14]

Panel B presents summary statistics on the wage distributions for each of the broader occupation groups. For most occupation groups and for most parts of the pay distribution, pre-period wages are well above the eventual minimum wage. Low-wage occupations stand out as the most likely to be impacted directly by minimum wage legislation. In 2013, a substantial share of their wage distributions fell below the eventual minimum wage.

3.3 Methodology

We estimate regressions of the form specified in equation 1. The subscript, i, indicates individuals or job ads. $s(i)$, $t(i)$, and $o(i)$ indicate the state, year, and occupation, respectively, that the individual is currently working in or the job ad is posted for. In our analysis of ACS data, observations are at the individual level. In practice, for BGT

[14]Workers in many of these low-wage occupations receive tips as part of their compensation. OES wage estimates are inclusive of tips. In Current Population Survey data, nearly half of individuals in the three lowest-paying occupations and about 15 percent of the remaining low-wage occupations respond "yes" to a question about whether they receive overtime, tips, or commissions. Importantly, while a lower "pre-tips" minimum wage may apply (as it does in most states), the sum of the base wage and tips is also required to equal or exceed the full minimum wage.

job ads data, we aggregate to the occupation-state-month, as explained in more detail in section 5. For both our ACS and BGT analyses, we estimate equation 1 separately for each of the occupation groups discussed above (i.e., "low," "modest," "medium," and "high" wage).

$$Y_i = \beta_0 + [Increaser_{s(i)} \times after_{s(i)t(i)}]\beta_1 + \boldsymbol{\theta_{s(i)}} + \boldsymbol{\delta_{t(i)}} + \boldsymbol{\alpha_{o(i)}} + \boldsymbol{X'_{s(i)t(i)}}\gamma + \epsilon_i \quad (1)$$

The outcomes of interest, Y, include variables describing the age and education levels of employed workers, as well as the desired skill level expressed by employers in their job postings. $Increaser_{s(i)}$ is an indicator equalling 1 if the state has a minimum wage change through new legislation at some point during our sample period (table 1). State categories are fixed throughout our sample period. The indicator $after_{s(i)t(i)}$ equals 1 if the time period, t, is on or after the date of the first minimum wage change in the state, s.[15]

All of our specifications include state, date, and occupation fixed effects ($\boldsymbol{\theta_{s(i)}}$, $\boldsymbol{\delta_{t(i)}}$, and $\boldsymbol{\alpha_{o(i)}}$, respectively). β_1 is therefore a difference-in-differences estimate of the effect of changes in the minimum wage on the outcome, Y. This most basic specification accounts for national-level time shocks and baseline differences in outcomes across states and occupations. The identifying assumption is that the outcome of interest would have followed similar trends across states if not for differential changes in their minimum wage policy regimes. As we will show, we do not see evidence of differential trends prior to the first minimum wage increase in the outcome variables. Standard errors are clustered by state.

We augment our most basic specification with controls for state-by-occupation and

[15]We also include an interaction between an indicator for indexer states and the after period, and report these results in the appendix.

occupation-by-year fixed effects. These additional controls allow for baseline differences in outcomes across states within a given occupation and for differential trends across occupations at the national level. We further include a range of controls that vary at the state-time level ($\boldsymbol{X}_{s(i)t(i)}$). Specifically, we control for state-level employment rates (obtained from the Bureau of Labor Statistics), log income per capita (from the Bureau of Economic Analysis), and a median house price index (from the Federal Housing Finance Agency). We also control for multiple factors related to the evolution of health insurance markets across states.[16]

The difference-in-differences regression in equation 1 treats all observations within a pre- or post-period the same, and all statutory minimum wage increases the same, regardless of the size of or distance in time from the increase. We explore alternative approaches below, including a linear specification for the minimum wage, as well as allowing for more flexible time dynamics within event-study specifications. With respect to both the structure of our estimators and our checks for threats to identification, our analysis quite closely mirrors analyses from recently published research in the minimum wage literature.[17]

[16]Specifically, we control for state take-up of the Affordable Care Act (ACA) Medicaid expansion (an indicator for whether the state has an expansion in effect in the given year, and a second indicator allowing this effect to vary after 2013, when ACA key coverage provisions were in effect). We also control for state-time variation in market concentration across the providers of insurance to both large and small employers from Kaiser: https://www.kff.org/state-category/health-insurance-managed-care/insurance-market-competitiveness/. These controls are used in Clemens et al. (2018), where we show that the same minimum wage hikes explored in the current paper reduce the likelihood that workers in low-wage occupations have employer provided health insurance. The benefits environment is important to control for here as well because, as we have shown, the interaction of minimum wages and benefits provision is complex.

[17]Careful examination of event-study estimates to check for pre-existing trends, for example, is a key element of the argument for econometric identification in both Cengiz et al. (2019) and Monras (2019). Examination of high-skilled or high-wage groups as a form of "falsification test" or "within-state control" is also familiar from Cengiz et al. (2019), as well as from Clemens and Wither (2019) and Clemens and Strain (2018b).

4 The Minimum Wage and Worker Demographics

In this section, we analyze the impact of state-level minimum wage changes on the skill level of employed workers using American Community Survey (ACS) data. We first describe the dataset, then provide results on worker demographics, then explore employment effects.

4.1 Data

The ACS is a household-based survey with relatively large samples, even within state-time-occupation cells. We restrict attention to the years 2011-2016 to align our ACS and BGT analysis samples. We limit our analysis sample to individuals between the ages of 16 and 64. We link ACS data for a given year to the state-level minimum wage applicable in July.[18]

The primary focus of our ACS analysis is on characterizing observable proxies (age and education) for the skill level of the individuals employed in low-wage occupations.[19] The top panel of Table 3 provides summary statistics for our key outcomes in each occupation group. Age and education levels rise, as one would expect, moving from low- to high-wage occupations. In low-wage occupations, the average age is 35, roughly 20 percent of workers are aged 16 to 21, a similar fraction lack a high school diploma, and 10 percent have completed a college education. In high-wage occupations, the average age is 43, only 1 percent of workers are aged 16 to 21 or lack a high school diploma, and 65 percent have completed a college education.

[18]Respondents in the ACS may be surveyed at any time during the calendar year, but the survey date is not available in the public-use files. We therefore impute the prevailing minimum wage at time of survey with that at the midpoint of the year. This problem is small, since all but a handful of minimum wage changes over this time period were in January of a given year.

[19]Aaronson and Phelan (2019) similarly focus their analysis on occupations in an investigation of the relationship between minimum wage increases and technological substitution, and in particular, definitions based on routine, manual, and cognitive tasks.

4.2 Results on Worker Demographics

Figure 1 gives a general sense of the relationship between state-level minimum wage changes and changes in one of our key outcome variables: the average age of the employed. Each panel presents this relationship for one of the four occupation groups.[20] States with minimum wage increases driven by inflation indexing provisions show up with small increases, totalling less than $1 across 6 years. For states with no minimum wage changes, the dividing point is 2014, which is the modal year in which states with statutory increases implemented their first change.

For low-wage occupations (Panel A), the best-fit line is upward sloping: states with larger minimum wage increases saw larger increases in worker age, while in states with no minimum wage change, average age decreased. The remaining panels show that the slope of the relationship between minimum wage changes and age is essentially flat for higher-paid occupation groups. These relationships are consistent with our expectation that effects will be concentrated among workers who are earning close to the minimum wage.

Table 4 presents regression estimates of equation 1 for those employed in low-wage occupations. The five panels correspond to different dependent variables: age and indicator variables for young adults (age 16-21), older adults (age 50-64), those without a high school diploma, and those with a high school or some college (but no college degree). The specification in column 1 controls for state, year, and occupation fixed effects. Column 2 adds two-way fixed effects at the occupation-by-year and occupation-by-state levels. Column 3 adds macroeconomic and health insurance market controls.

We find that states with statutory increases in the minimum wage see the average age increase in these occupations, rising by about a quarter of a year following a minimum

[20]The age change is the average difference between the period before a given state enacted its first minimum wage increase to the period from the first change onwards (see Table 1). Minimum wage changes on the x-axis are the total change for the state over the full time period.

wage hike. Panel B shows that the age effect primarily manifests through a nearly 1 percentage point drop in the young adult employment share (or 5 percent off a base of 21 percent). Panel C shows that about half of the shift away from young adults loads onto increases in employment of older adults (age 50 plus), implying that the remainder is split among prime-age workers. These age effects are generally significant at the 1 percent level and remain fairly consistent in magnitude with the addition of more controls.

We also find effects on average education. Specifically, low-wage workers are more likely to have a high school diploma or some college education following a minimum wage hike. The decline in employment share for those without a high school diploma is just over half of a percentage point (4 percent on a base of 17 percent), is statistically significant at the 5 percent level, and is almost exactly offset by the increase for high school and some college.

A back-of-the-envelope calculation using estimates from Mincerian earnings regressions puts these numbers into perspective (Mincer, 1974; Lemieux, 2006). Estimated on ACS data from our sample period, an earnings regression for full-time workers yields an annual earnings gain of roughly 7 percent per year of experience among the young. We estimate that workers in low-wage occupations are roughly a quarter of a year older following minimum wage increases. This translates into roughly a 1.75 percent increase in dollar terms, as implied by the Mincer regression (7×0.25). Table 2 can be used to contrast this estimate with the magnitude of the wage increases made necessary by the minimum wage changes we analyze. Across all workers in low wage occupations, the required increase averaged around \$0.30.[21] This dollar value corresponds to a roughly

[21]This estimate requires rough integration over the percentiles that are reported in the OES data. At the 10th, 25th, and 50th percentiles for low wage occupations, the average minimum wage increase we analyze forced wages to rise by roughly \$1, \$0.50, and \$0.10, respectively. For the top half of the distribution, there is essentially no effect.

3 percent increase from the $11 mean wage for low wage occupations. The dollar increase associated with having older workers implied by the Mincer estimate thus has a magnitude of just over half the wage increase required by the minimum wage changes (comparing 1.75 percent to 3 percent).

Therefore, although the level of our effect is quite small, the implied effect per dollar minimum wage increase is quite large. The equivalent estimate for changes in educational attainment are much more modest. We estimate that workers in low wage occupations are 0.6 ppts less likely to lack a high school diploma following a minimum wage increase. In the Mincer regression, we estimate a 35 log point return to having high school or some college education. Multiplied by the modest 0.6 ppt estimate, this implies a 0.2 percent increase in dollar terms which is on the order of 7 percent of the wage increase required by the minimum wage changes.

Thus the education effects are much smaller in magnitude than the age effects in dollar terms as well. When we probe these effects further, we find that the high school diploma effect operates primarily via the age effects. In panel B of Appendix Table A.2, we do not see effects for older adults without a high school diploma, but rather among young workers who may not have completed their schooling yet. We return to this point in section 6 after discussing the job vacancy results.

We next estimate a version of equation 1 that tracks the dynamics of the minimum wage effect. Specifically, we allow for interactions between state group ($Increaser_{s(i)}$) and indicators for each year in event time before and after the first minimum wage change. The omitted category is the year prior to the first minimum wage change. We plot the coefficients in Figure 2 for three dependent variables: Age, Young Adult, and Dropout. The other outcomes (Older Adult and High School/Some College) mirror these. For all outcomes, effects emerge only after the first minimum wage increase – we see no evidence of differential trends prior to minimum wage increases. Furthermore,

effects widen with time since the first minimum wage increase took effect. It could be that the employment stock updates more slowly than, say, new hires, or because firms make a variety of gradual adjustments (for example, it may take time to adopt different production technologies that necessitate more-skilled workers).[22] Effects may also widen because minimum wage policy compounds – each state had at least two increases over this time period. In section 5, we obtain a better understanding of the underlying mechanisms for these dynamics with the BGT data.

We also explore different functional forms. Appendix Table A.1 reports results from regressions that use the linear, contemporaneous minimum wage (including inflation-pegged increases) as the key explanatory variable. We also report coefficients on the Indexer*After variable from the main specification. In the linear specification, age effects remain strongly statistically distinguishable from zero, while education effects are small and insignificant. Results are attenuated in the linear specification because effects for inflation-indexed minimum wage changes tend to be small and insignificant. As in Brummund and Strain (2020), it is clear that states operating under inflation indexing regimes have had different experiences than states implementing new statutory increases. Another way to see this is in appendix figure A.1, which explores whether effects vary with the size of the minimum wage increase (also including inflation-pegged increases). Consistent with the non-linearities discussed above, we find only small effects for the smallest minimum wage increases, and larger effects (of similar magnitudes) for medium and large minimum wage increases.[23]

We next examine whether effects are present for higher earning occupations. Figure

[22]See Meer and West (2016), Sorkin (2015), and Aaronson et al. (2018).

[23]As noted above, the labor-labor substitution channel falls in the middle of the chain of effects one might naturally anticipate as the minimum wage becomes increasingly binding. For example, to accommodate a small minimum wage change a firm might impose stronger effort requirements, before substituting for higher-skilled labor, and then finally replacing workers with capital or shutting down production. As jobs disappear altogether, the minimum wage's effects on the skill mix of those employed may flatten or even reverse.

3 provides a summary of this analysis. Here we present estimates separately for each wage decile. We also disaggregate the low-wage group into the bottom three occupations ("very low") and the remainder (labeled with "1"). We estimate equation 1 separately for each group using the full set of controls. The very low and the remainder of the low-wage occupations exhibit pronounced responses, with magnitudes for the very low wage group roughly double the magnitudes for the remainder. For higher deciles, the estimates are, with few exceptions, very close to zero. Appendix Table A.3 provides regression coefficients for the aggregated occupation groups and confirms that occupations that earn well above the minimum wage see no effect. This result is reassuring in that if states that implement minimum wage hikes were already seeing broad-based skill increases, we would expect to see these trends in higher-paying occupations as well.

Finally, Appendix Table A.4 reports results for other outcomes. We explore a range of demographic characteristics, including race, gender, foreign-born status, and whether the individual recently migrated from another U.S. state. With few exceptions, estimates are small in magnitude and statistically insignificant.[24]

4.3 Employment

We have presented evidence of modest upskilling among those employed in low-wage jobs. The average skill level could rise either because the least-skilled are replaced with higher-skilled workers or because the jobs held by the least-skilled individuals simply disappear. Table 5 presents evidence on the employment, hours, and weeks worked in each of the occupation groups.[25] We find that the impacts of the minimum

[24]The immigration margin is of potential interest in light of analysis by Smith (2012), who finds evidence that adult immigrants sometimes replace teenagers upon their arrival in a labor market. However, we do not see a relationship between the minimum wage and this type of substitution.

[25]We include full controls except the employment rate and occupation fixed effects, since the dependent variables in this analysis involve occupation-specific employment.

wage on each of the outcomes are small, economically and/or statistically.

In Panel A, we explore the population share of those employed in a given occupation group. There is a marginally significant positive effect for low-wage occupations; the magnitude is small and we can rule out employment declines larger than one hundredth of one percentage point and employment increases larger than one quarter of one percentage point with 95 percent confidence. This is accompanied by a small decline in employment within modest wage occupations. Panel B shows that, among the employed, low-wage occupations do not lose their employment share following minimum wage increases. It also gives an indication that the more-skilled workers found in low-wage occupations might be coming from those previously employed in modest-wage occupations. The latter lose employment share, though the magnitudes are small.[26]

Panels C and D show that, conditional on being employed, hours and weeks worked by workers in low-wage occupations remain fairly constant. In the low-wage occupations we see a modestly significant increase in weeks worked – on the order of one-fifth of a week increase over the year – significant at the 5 percent level. In the high-wage occupations we see a decrease of less than one-tenth of a week. Although this increase is statistically significant, it is quite small, amounting to just over a 0.1 percent decrease in weeks worked among individuals in high-wage occupations. Given the prevalence of statistically insignificant point estimates in this table, we suspect this result is best explained as a product of sampling variations.

Overall, the effects we estimate on occupation-level employment are small. This suggests that our results on the skills of those employed within low-wage occupations are driven by a replacement of lower-skilled workers with higher-skilled workers, rather than jobs held by the least-skilled workers simply disappearing.

[26]This is consistent with a supply-side force emphasized by Phelan (2019), whereby minimum wage increases lead workers to prefer jobs in which wages rise to jobs which previously had modestly higher wages but worse non-wage amenities.

Thus far, we have found that total employment in low-wage occupations remains fairly constant following a minimum wage increase, but that there is a decrease in the likelihood that these jobs are held by the young and less educated. This makes it natural to ask two questions. First, has overall employment among low-skilled groups declined, and second, who are the slightly higher-skilled workers who have taken their place? Table 6 speaks to these questions. Here we examine employment-to-population ratios (epop) and the out-of-labor-force (olf) population share by demographic group. Panel A provides a benchmark for the overall epop and olf share and shows that both dimensions were unaffected by new minimum wage legislation. Estimates for the epop are economically very small and, with full controls, we can rule out effect sizes outside of plus or minus 0.4 percentage point with 95 percent confidence. Point estimates for the olf share are small and statistically insignificant, though our 95 percent confidence interval of [-0.2ppt, 0.8ppt] includes some increases that are fairly sizable.

Panel B shows differential impacts by age group. All specifications include age group main effects as well as our baseline or full sets of controls (columns 1 and 3, respectively). To these controls, we add interactions of demographic group indicators with our minimum wage policy variables, as well as interactions with the state and year fixed effects.[27]

Focusing first on the coefficient for Increaser*After, we see that the epop fell for the omitted category, Age 16-21. For example, in column 3 with full controls, we find a nearly 1 ppt drop in employment probability for this group following a new minimum wage law.[28] Columns 3-6 show increases in the olf rate for young adults that are almost

[27]We exclude occupation fixed effects and the employment rate because the dependent variable is employment. All regressions in panel B also include indexer indicators interacted with demographic group.

[28]This estimate is in line with prior estimates from Clemens and Strain (2018a), who analyze the same minimum wage changes using the same data with a modestly different specification. In panel B of table 7, Clemens and Strain (2018a) report an estimate of negative two percentage points for employment among individuals ages 16 to 21 in states that enacted particularly large minimum wage changes, and an estimate just under one percentage point in states that enacted relatively modest minimum wage changes.

the same magnitude as the epop declines. This result implies that the epop decline largely manifests through an increased propensity to be out of the labor market, as opposed to being unemployed.

The interaction terms indicate the differential impact of minimum wage changes on older workers. Estimates for the epop are positive, significant, and at slightly larger magnitudes than the main effect. Thus, the reduction in employment of the young is drawn from slightly higher epops of prime age workers. The overall effects for these older age groups (the sum of the coefficient for their own category and the main effect) are modestly positive, and offset the impact on the young. Because these overall effects are small, it is difficult to tease out whether increased employment of older workers is sourced from those who were previously out of the labor force or the unemployed. Point estimates on the interaction terms for the olf rate suggest that older workers were drawn mainly from the unemployed, though this conclusion depends on the specification; standard errors are such that we cannot rule out the effects are driven entirely by one margin or the other.

5 The Minimum Wage and Skill Requirements in Vacancy Postings

Results from the ACS indicate a shift in the composition of the low-wage workforce. However, these effects on the stock of employment may be driven by effects on the supply of workers as well as employers' labor market practices (Acemoglu, 2001; Flinn, 2006; Adams et al., 2018). Consequently, the underlying mechanisms remain unclear. Further, because the ACS contains no information on the firms that employ these workers, it is difficult to examine whether within- or between-firm changes are driving the results. We now focus on job postings, which allow us to make progress on these issues while

investigating one of the first channels through which firms might act, should they desire to change their skill mix.

5.1 Burning Glass Data

Our data consist of over 100 million electronic job postings in the United States from 2011-2016. These job postings were collected and assembled by Burning Glass Technologies (BGT), an employment analytics and labor market information firm. BGT obtains job postings from some 40,000 online job boards and company websites. It then parses and de-duplicates the postings into a systematic, machine-readable form. Thanks to the breadth of coverage, BGT believes its database captures a near-universe of online job postings. The posting-level data were first used by Hershbein and Kahn (2018) to study changes in skill requirements and production technology following the Great Recession.[29]

The key advantages of our data are its breadth and detail. The BGT data contain about 70 possible fields for each vacancy. We exploit detailed information on occupation, geography, skill requirements, and firm identifiers. The codified skills include the traditional stated education and experience requirements.[30] They also include thousands of "key word" skills standardized from open text in each job posting.[31] Deming and Kahn (2018) distill these thousands of words into a categorization of 10 general

[29]The dataset used in the current paper was provided in April 2017. Although BG's algorithms for removing duplicates and coding ad characteristics changes over time, each iteration is applied to all postings in the data. The database also includes years 2007 and 2010, but unfortunately lacks postings from 2008 and 2009. We focus on the window around the recent statutory minimum wage increases that also avoids the Great Recession and its early recovery. Results are similar if we include the 2010 data.

[30]Ads can specify a minimum requirement and a preferred requirement. We use the minimum, as it is much more prevalent, and classify an ad to a single category based on the minimum necessary (e.g., an ad for a job requiring a Ph.D. will not also be coded as requiring a high school diploma).

[31]For example, an ad might ask for a worker who is bilingual or who can organize and manage a team. BGT cleans and codes these and other skills into a taxonomy of thousands of unique but standardized requirements. Beginning with a set of pre-defined possible skills, BGT uses machine learning technology to search text in an ad for an indication that the skill is required.

skills. We use three of these in our analysis, namely "Customer Service," "Cognitive," and "Non-cognitive," and also add an English-language requirement and a computer skill requirement.[32]

The BGT data are not without disadvantages. First, vacancy postings represent the stated preferences of firms rather than details of the process by which the position was actually filled. We view these data as capturing a potential first line of firms' responses to minimum wage policy.

A second issue to consider is representativeness. That the BGT data only cover postings on the internet is a drawback, though by 2014 between 60 and 70 percent of all job postings could be found online (Carnevale et al., 2014).[33] Vacancies in general will be somewhat skewed towards certain areas of the economy since they overrepresent growing firms (Davis et al., 2013). However, two-thirds of hiring is replacement hiring (Lazear and Spletzer, 2012). In the high-churn, low-paying occupations of primary interest for minimum wage analyses, we have a good deal of coverage.

Figure 4 shows the occupation distribution of BGT compared to the employment distribution in OES over the same years. Of course, stock of employment does not necessarily equal vacancy postings for a number of reasons, but it gives some intuition for where BGT might be lacking in coverage. Note that all low-wage occupations (indicated with triangles) are below the 45-degree line, meaning they are underrepresented in BGT

[32]The Customer Service requirement includes any ad with one of the following key words: "customer," "sales," "client," "patient." Non-cognitive skill requirement includes the key words "organized," "detail-oriented," "multi-tasking," "time management," "meeting deadlines," "energetic." Computer requirement is a range of programs and languages that BGT classifies. Cognitive skill requirements involve the keywords "research," "analy*," "decision," "solving," "math," "statistic," or "thinking." English requires the ad to have the keyword "English."

[33]Carnevale et al. (2014) show that the occupation-industry composition of the BGT data are similar to that of the Conference Board's Help Wanted Online Index. Moreover, the authors audited a sample of job postings in the BGT database and compared them to the actual text of the postings, finding that the codings for occupation, education, experience were at least 80 percent accurate. This figure should be higher in our extract since BGT regularly revises and attempts to improve its algorithms, applying them retroactively on the complete historical database of postings.

relative to OES employment. However, they still have a large presence: for example, cashiers (SOC code 4120) make up 4 percent of all ads posted and servers (SOC code 3530) make up 1.6 percent. Importantly, panel B shows that there are few changes to the composition of the data over time. Here, we map the 2011-13 deviation of occupation share between BGT and OES on the 2014-16 deviation. If representation has remained constant over the two time periods, points will line up on the 45 degree line. For the most part, this is exactly what we see. That there are not large shifts in the BGT occupation distribution, relative to OES employment, over our time period is reassuring that results using BGT are internally valid.[34]

To better understand any changes to representativeness as a function of minimum wage law, we compare the occupation ad share in the state and year in BGT data to the occupation employment share in OES data. We regress the deviation between the two occupation shares on our key right hand side variables. Results are reported in Appendix Table A.5, panel A.[35] The coefficient on Increaser*After indicates whether there is a systematic change in representativeness in BGT for the baseline occupation group, low-wage occupations, and the interactions with other occupation groups show whether there is any differential effect. The coefficients tend to be very small and statistically insignificant in our baseline specifications. The dependent variable (the deviation between occupation shares) averages zero with a standard deviation of roughly 0.01. The point estimates are all at least an order of magnitude smaller than 0.01 and the standard errors are one to two orders of magnitude smaller. In the specification with the fewest controls, the coefficients are statistically significant, though still very small in magnitude. But

[34]See also Hershbein and Kahn (2018) who discuss the representativeness of the BGT data at great length in their data appendix. They show that the distribution of ads across occupations is fairly stable over time.

[35]Because OES data are a three-year moving average, we restrict attention to OES years 2013 and 2016, and link to BGT averages from 2011-2013 and 2014-2016, respectively. Similarly, our "after" variable and applicable control variables are three-year averages.

the magnitudes fall and most become statistically insignificant with the inclusion of the two-way fixed effects. Once we control for the small differential changes in representativeness across occupations over time (occupation-by-year effects), we see no differential changes in our comparisons between states that enacted new statutory minimum wage increases and states that did not. Appendix Table A.5 is therefore reassuring that our analysis using the Burning Glass data is internally consistent.

With ad-level data, we can measure the relationship between skill requirements and the minimum wage at fairly high frequencies. We aggregate to the monthly level and continue to classify occupations at the four-digit SOC level. We therefore link state minimum wage variables on a monthly basis. We estimate regressions at either the occupation-state-date (year-month) level, weighting by OES employment to peg the BGT sample more closely to the ACS, or the firm-occupation-state-date level, weighting by ad share within occupation-state-date multiplied by OES employment for precision. Our weighting for the more disaggregated cells allows us to estimate regression specifications at any level of aggregation and obtain the same result. To reduce noise, we restrict to occupation-state-date cells that have at least 10 ads (98% of ads in our preferred sample).

We restrict our main BGT sample to observations for which the variable linking the ad to an employer is non-missing. We further restrict to employers that regularly post jobs in low-wage occupations, defined as those that post in at least 20 months and 20 states.[36] We show below that these criteria generally do not impact our main results, especially for our full-controls specification, but are helpful for interpreting specifications in which we include firm fixed effects. Furthermore, panels B and C of Appendix table A.5 shows that the probability of meeting our sample criteria does not vary systematically with minimum wage changes, again, once we include occupation-by-year effects.[37]

[36]The restriction on non-missing firm drops 35 percent of low-wage ads, while the coverage restriction drops 25 percent of remaining ads. Ads with a missing firm are likely posted by a recruiter's website.

[37]These panels report regression analysis for the share of ads in an occupation-state-month cell that

The bottom panel of Table 3 summarizes skill requirements found in the BGT data. There is a clear positive correlation between the likelihood of an education requirement and an occupation's position in the wage distribution; for example, 30 percent of low-wage job ads have an explicitly-stated education requirement, while 70 percent of high-wage jobs have one. Hershbein and Kahn (2018) show that the prevalence of education requirements are strongly correlated with the education level of employed workers at the occupation and MSA levels. At the same time, requirements that appear in job postings may not translate one-for-one into the requirements imposed in practice.

The bottom rows of Table 3 give cell sizes and the number of ads posted overall and within each occupation-state-month cell. For low-wage occupations, we have over 28,000 cells, 5.6 million ads, and an average of almost 200 ads per cell.

Our empirical analysis focuses primarily on the high school diploma requirement because it is objective and has substantial relevance to minimum wage occupations. It translates directly into the demographics analyzed in the ACS: increases in an enforced high school requirement will both reduce employment by high school dropouts and reduce employment among individuals 18 and younger. We also present results for the other skill requirements summarized in Table 3. However, at baseline, some of these requirements (computer skills, cognitive skills, and English language) are much less prevalent among low-wage occupations, so we might not expect as much of a response.

5.2 Results on Skill Requirements

Figure 5 presents the raw relationship between state-level changes in the minimum wage and the prevalence of the high school diploma requirement. A positive correlation is most evident for low-wage occupations (Panel A). States with large minimum wage

meet various sample selection criteria. Once occupation-by-year fixed effects are included, coefficients on our key minimum wage variables are with one exception tiny and insignificant.

increases saw larger increases in the prevalence of the high school requirement, on average, than either states with small minimum wage increases or states with no minimum wage increases. In contrast, the best-fit lines are flatter for the modest-, middle-, and high-wage groups, as presented in the remaining panels.

We next present estimates of equation 1 for the BGT data, where each observation is an occupation-state-month cell. Table 7 shows the results for low-wage occupations, with the high school requirement as the dependent variable. We find a positive, and statistically significant increase in the prevalence of the high school diploma requirement in states that enacted new statutory minimum wage increases. In our least-controlled specification, the estimated effect is an increase of 1.8 percentage points in the share of jobs with a high school diploma requirement. Column 3 shows that we obtain a moderately larger estimate, of 3.35 percentage points, when we control for state-time variation in macroeconomic conditions, as well as for occupation-by-date and occupation-by-state fixed effects. This 3.35 ppt increase translates into a 13 percent increase (off a base of 26 percent).[38]

We can again benchmark the magnitude of this skill increase using the earnings differentials that are predicted by a Mincerian regression of earnings on age and education. The differential associated with having a high-school educated worker is 35 log points. A 3.3 ppt increase in the skill requirement thus corresponds with a 1.2 percent earnings differential ($3.3 \times 0.35 = 1.2$ percent). This is roughly a third the size of the average increase in wages imposed by the minimum wage hikes in our sample (that is, the imposed wage increase averaged roughly 3 percent). This falls between the estimates we

[38]The fact that the inclusion of macroeconomic controls results in a larger point estimate is not entirely surprising, as the statutory minimum wage increases were more prevalent in states that experienced strong housing recoveries and overall economic growth (Clemens and Strain, 2017). Failing to control for these developments will tend to attenuate estimates of the effects of minimum wage increases over this time period. Notably, however, the inclusion of these controls has only modest implications for the ACS analysis presented in the previous section.

found for increases in age (1.75 percent) and education (0.2 percent) among individuals employed in low-wage occupations in the ACS.

Figure 6 shows the event study version of equation 1 for high school requirements. We include the controls listed in column 3. To reduce noise, we aggregate from the month to the quarter level. The omitted category is the quarter prior to the first minimum wage change. There are no obvious trends prior to that first change, but there is a marked increase immediately following that first change. The elevated level is consistent through the full range of the post-increase data (20 months). Estimated effects are fairly constant here, while in the ACS data we observed impacts on worker demographics that increased with time since the first minimum wage increase (Figure 2). This combination of findings is consistent with the interpretation that stock variables take time to reflect changes in employment flows. The sharp response of text in job postings may also be related to lags between the legislation and enactment of minimum wage increases. That is, forward looking firms may begin contemplating personnel changes when wage increases are legislated, then implement those change when increases go into effect.

Appendix Table A.6 explores robustness to our main sample selection criteria for low-wage occupations. Here we explore samples that relax or strengthen the requirement that firms post regularly in low-wage occupations. With full controls (column 3), results are very similar across samples regardless of the restriction. Failing to control for variations in macroeconomic conditions results in statistically insignificant point estimates in analyses of two of the alternative samples.[39] Looking across samples, the analysis reveals further that changes in skill requirements were stronger among firms that advertise for low-skilled workers with regularity, compared to those that hire such workers sporadically.

[39]This reveals, once again, the importance of accounting for the fact that recent minimum wage increases have been enacted primarily by states that were experiencing relatively strong economic expansions.

Appendix Figure A.1 and Table A.1 explore how effects vary with the size of the minimum wage increase. In general, we do not see effects for states that had inflation-indexed increases and effects level off for large compared to medium increases. Nonetheless, we report results from a linear specification in panel D of Appendix Table A.1. With the full set of controls included, a one-dollar increase in the minimum wage is associated with a statistically significant increase of 1.45 percentage points in the share of low-wage job postings that require a high school diploma.

Figure 7 shows estimates separately by decile of the occupation's 10th percentile wage. We again break the bottom three occupations out into a "Very Low" category. Effects are concentrated at the bottom of the distribution, with the largest impact seen among bottom-decile occupations excluding those we classify as "Very Low." One possible explanation is that high school diploma requirements are a less important screening mechanism for those three lowest-ranked occupations, as evidenced by their lower prevalence at baseline: only about 16 percent of Very Low wage occupations post a high school requirement, compared to 31 percent for the remainder. Expressed as percent changes, our point estimates are thus quite similar for the "Very Low" and "Low" wage groups.

Coefficients for the remaining deciles in the distribution are smaller and tend to be statistically insignificant. The third, fourth, and fifth deciles have sizeable point estimates that are marginally significant. The modest and middle wage occupation groups have the largest propensity to post a high school requirement. In percent changes, effects are monotonically decreasing with the decile of the occupation's 10th percentile wage (except for the second decile where we see no effect). Appendix Table A.3 provides regression results for ads across broader occupation groups. Coefficients are uniformly smaller for modest-, middle-, and high-wage occupations than for low-wage occupations, and tend to be statistically insignificant. The average point estimate across these

higher-skilled groups is less than one-fifth of the point estimate associated with the low-wage occupations and has a t-statistic of less than 1.

Appendix Table A.7 examines other outcomes. Reassuringly, we see no effect on the propensity to require a college degree. Given the low representation of college graduates and college degree requirements among low-wage occupations (Table 3), we would not have expected to see any adjustment on this margin.

With respect to other skill requirements, our preferred specification yields a statistically significant and positive point estimate on the "customer service" requirement and statistically significant and negative point estimates on the "cognitive" and "computer skills" requirements. We interpret these results with caution, as these estimates are less stable than our high school diploma finding across alternative specifications. Further, the observed mix of positive and negative point estimates makes it difficult to connect this set of results to a coherent theory. One pattern of potential note is that we find an increase in the most common of the remaining skill requirements following minimum wage hikes (customer service), while we observe a decrease in two of the least common of the remaining skill requirements (computer and cognitive skill). This pattern could be viewed as consistent with the idea that minimum wage occupations become more specialized following minimum wage increases. Specialization may, in turn, be associated with a decrease in opportunities for improving on skills outside of the relatively narrow customer service function. Finally, the customer service result is consistent with the idea that minimum wage hikes may increase investments in capital equipment, like automated ordering kiosks, which come with hands-on customer service requirements in their initial years (Lordan and Neumark, 2018; Aaronson and Phelan, 2019).

Finally, we investigate whether the increase in high school requirements is being driven by changes within or between firms. Recall, above we discussed that labor-labor substitution might occur because the composition of jobs shifts towards firms that em-

ploy slightly higher skilled workers (between firm) or because a given firm substitutes its lower skilled workers for slightly higher skilled (within firm). For this analysis, we disaggregate the data to state-month-occupation-firm cells. In table 8, we present estimates of equation 1, beginning with the full controls specification that was discussed previously. As replicated in column 1, statutory minimum wage increases are associated with a 3.3 percentage point increase in the prevalence of high school requirements. To this specification we then sequentially add firm, firm-by-state, and firm-by-year fixed effects.

In specifications that include firm fixed effects, we find that new statutory minimum wage increases predict a 1 percentage point increase in the prevalence of the high school requirement. This means that the between-firm margin of adjustment can account for roughly two-thirds of the overall effect, while the within-firm margin accounts for roughly one-third. This is consistent with recent work by Sorkin (2015) and by Aaronson et al. (2018), who emphasize the importance of firm-level exit and entry for understanding the minimum wage's long-run effects. That being said, even accounting for variation across firms in posting behavior, average differences within a firm across states, and changes within firm over time, we still find a sizable role for within firm responses to minimum wage policy. The effect is statistically significant and economically meaningful. This latter specification also helps to alleviate concerns that omitted variables drive our result. Controlling for the typical posting behavior of a firm, controlling for how the firm typically posts in a given state, and controlling flexibly for nationwide changes in firm posting behavior over time, we still find evidence of a shift towards more productive workers within firms.

6 Discussion

In this section we discuss how our analyses of data from the ACS and BGT relate to one another, as well as how they relate to the conceptual framework we sketched in section 2. We first discuss the potential mix of supply and demand side forces underlying our results. We then discuss the relationship between the results we find on age and education in the ACS and BGT data. Finally, we discuss the magnitudes of our estimates as they relate to the cost increases firms experience following minimum wage increases.

6.1 The Roles of Labor Demand and Supply

There are several potential explanations for the changes we observe in both employment and posted skill requirements. The most direct demand-side explanation is that employers are searching for and finding more-productive employees in response to increased labor costs. A second, complementary explanation is that there may also be a change in the composition of firms that choose to post vacancies and make hires. Firms that use unusually low-skilled labor, for example, might be replaced by firms who use higher-skilled workers for similar occupations.

Among these demand side explanations, our analysis suggests important roles for both. Both our ACS and BGT analyses are consistent with the view that demand shifted towards higher-skilled workers both within and across firms. Either margin may explain our findings in the ACS, which capture the stocks of workers employed in low-wage occupations. Our BGT analysis, which allows us to track firms across both time and space, can affirmatively rule in both the within- and across-firm margins (see table 8). The between firm margin operates through an increase in employment share of firms employing higher skilled workers. Because we found no overall change in employment levels or shares across occupation groups, it must be that the firms employing higher

skilled workers saw an increase in their employment levels, while firms employing lower skilled workers saw a reduction.[40] As posited above, the gain among higher skilled firms can happen because their competitors face a binding cost shock.

Two of our findings point to likely roles for supply side factors. First, our ACS analysis finds that young and low education workers are replaced by older workers. This appears to involve some combination of labor market entry and shifts of older workers across occupations.[41] Because employment increases are quite diffuse across individuals in higher age groups, however, we cannot speak with precision to who these individuals are.

Second, our BGT analysis suggests that minimum wage increases led to changes in skill requirements for some occupations that are not directly affected by the minimum wage. As noted in the discussion of our conceptual framework, the pre-screening function of vacancy postings can lead posted requirements to change in response to actual or expected changes in the supply of applicants. If a minimum wage increase leads low-skilled individuals to apply for jobs for which they are not qualified, pre-screening requirements may rise even if firms do not plan to alter the skill mix of the workers they ultimately hire. Notably, the occupations in which we observe these responses made extensive use of the high-school diploma requirement at baseline. The pre-screening margin thus appears to be a plausible rationale for these increases in requirements.

6.2 Age vs. Education

We see robust evidence that employers increase stated preferences for a high school diploma immediately following a minimum wage increase. In the ACS, we see commen-

[40] Additional analysis of the number of postings in the BGT data is consistent with this result. In Appendix Table A.8, we report no change in the number of postings across occupation groups.

[41] This combination of factors is implied by the fact that we see neither a decline in overall employment nor a decline in employment within low-wage occupations.

surate decreases in employment probabilities for the young and less educated. As noted previously, however, those results load primarily on age and not on education per se. It is thus natural to ask how these analyses connect.

Why might firms post education requirements as a means to, in practice, increase the age of their typical employee? Several factors may be at work. First, it is important to note that high school diploma requirements will mechanically impact the young, who are precisely the age group within which we observe declines in employment. The linkage between our ACS and BGT findings is thus more direct than one might initially think. A second point is that the expected impact of a skill requirement depends on how it will be interpreted by potential applicants. It is not unreasonable to speculate, as firms seemingly do, that a high school diploma requirement may be an effective way to convey that the very least-skilled applicants need not apply. Third, although the young are not a protected class under federal anti-discrimination law (which explicitly protects those over the age of 40), the young are nonetheless a protected class in several states. Given that the federal law introduces age as a protected class, firms may simply prefer not to appear to discriminate by age even in cases where it is not, strictly speaking, illegal. They can instead accomplish a reduction in youth applications by posting a diploma requirement.

6.3 Quantifying Adjustments in the Context of Firms' Costs

We conclude this section by attempting to quantify the magnitudes of our estimates relative to the cost increases firms experience as a result of minimum wage changes. On this score, the analysis in the current paper complements our analysis in Clemens et al. (2018). There, we provide evidence that this same set of minimum wage increases predict modest declines in the likelihood that workers in low-wage occupations have employer provided health insurance. While cost savings from reductions in coverage may help

firms to offset the added expense generated by minimum wage hikes, we estimate that such cost savings are modest. The estimated reduction in health benefits offsets roughly 10 to 15 percent of the wage increase on an annual basis.

Our analysis in the current paper finds that minimum wage increases lead to increases in the age and education of workers in low-wage jobs. In section 4.2, we used a simple Mincerian earnings regression to assign a value to the estimated effects. There we found that the age effect amounted to more than 50 percent of the mechanical minimum wage increase. In section 5.2, we conducted a similar exercise for increases in posted high school diploma requirements. There we found that the effect on postings amounted to roughly one third of the mechanical minimum wage increase. Were we to equate Mincerian earnings differentials with productivity, we could then say that labor-labor substitution allowed firms to offset a much larger fraction of the cost increase than offsets associated with health insurance benefits.

Between upskilling and declines in employer provided health insurance, our analyses can thus account for roughly half to two-thirds of the increase in the cost of workers in low-wage occupations. Other non-wage aspects of compensation, as well as non-compensation job attributes like effort requirements, may bring this fraction closer to one. Personnel policies thus appear capable of going a long way towards explaining how firms respond to minimum wage changes.

7 Conclusion

We investigate whether changes in firms' skill requirements are channels through which labor markets respond to minimum wage increases. We present evidence on two sets of outcomes: observable skill proxies and the skill requirements firms include in online job postings. Data from the American Community Survey show that recent

minimum wage changes resulted in increases in the average age and education of the individuals employed in low-wage jobs. Data on job vacancy postings show that the prevalence of a high school diploma requirement increases at the same time. The shift in skill requirements begins within the first quarter of a minimum wage hike. Further, it results from both within-firm shifts in postings and across-firms shifts towards firms that sought more-skilled workers at baseline. Given the poor labor market outcomes of individuals without high school diplomas, and the importance of early experiences for career outcomes (Kahn, 2010), these findings have substantial relevance for the well-being of individuals at the low end of the earnings distribution.

Our analysis of the stock of employment is limited in at least two respects. First, ACS data provides a fairly coarse look at the demographic characteristics of the employed, and may thus miss many interesting margins along which employment patterns change. Second, like most analyses of employment stocks, our ACS analysis is inevitably limited to capturing short-to-medium run responses of margins that may take years to fully adjust.

While our data on vacancy postings allow us to shed light on a unique aspect of firms' hiring behavior, there are limitations here as well. For instance, the BGT data do not provide a perfectly representative picture of the job-vacancy landscape. Furthermore, without being able to match stated requirements to realized hires, we cannot discern whether firms successfully implement their formal requirements and we also cannot observe whether firms without formal requirements achieve the same skill distribution via informal hiring policy. However, the combination of an immediate shift in stated requirements, as seen in the BGT data, accompanied by a gradual increase in the skill level of the employed, as seen in the ACS data, suggests that we are indeed observing labor-labor substitution in response to minimum wage hikes.

In Clemens et al. (2018), we showed that these same minimum wage increases re-

sulted in lower provision of employer provided health insurance in low-wage occupations. Our estimates imply that savings from reductions in coverage offset about 10 percent of wage increases generated by the minimum wage hikes, leaving a sizable role for the shifting of rents to workers. The current paper's evidence on labor-labor substitution suggests that productivity in minimum wage jobs simultaneously increased due to changes in firms' hiring policies. We estimate that these effects can account for an additional offset of roughly a third to 50 percent, based on standard Mincerian returns to education and experience. Additional research on firms' hiring policies, production processes, and compensation packages has the potential to further advance our understanding of firm-level responses to minimum wage increases.

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Figures and Tables

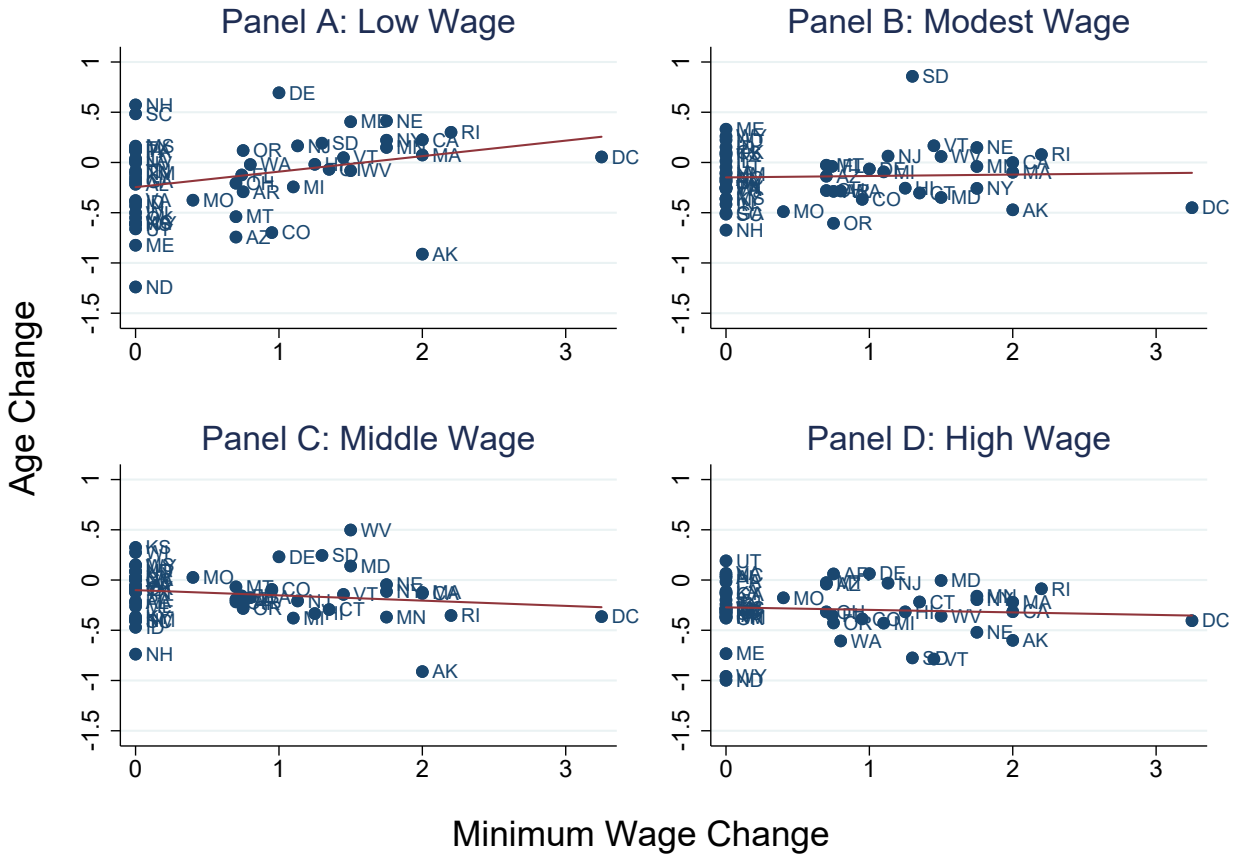

Figure 1: **Changes in Age of Employed (ACS) and Minimum Wage by State**
Note: The figure presents scatter plots of the state-level change in average age of employed workers on the state-level change in the minimum wage, separately by occupation group, using American Community Survey (ACS) data. The age change is the average difference between the period before a given state enacted its first minimum wage increase to the period from the first change onwards (see Table 1). Minimum wage changes on the x-axis are the total change for the state over the full time period. For states with no minimum wage change, we use the modal change date of statutory increasers, 2014. We group occupations based on their decile of the 10th percentile wage distribution, as measured in the 2006 Occupational Employment Statistics. "Low", "Modest", "Medium", and "High" wage occupations correspond to the 1st, 2-4, 5-7, and 8-10 deciles, respectively; see Table 2.

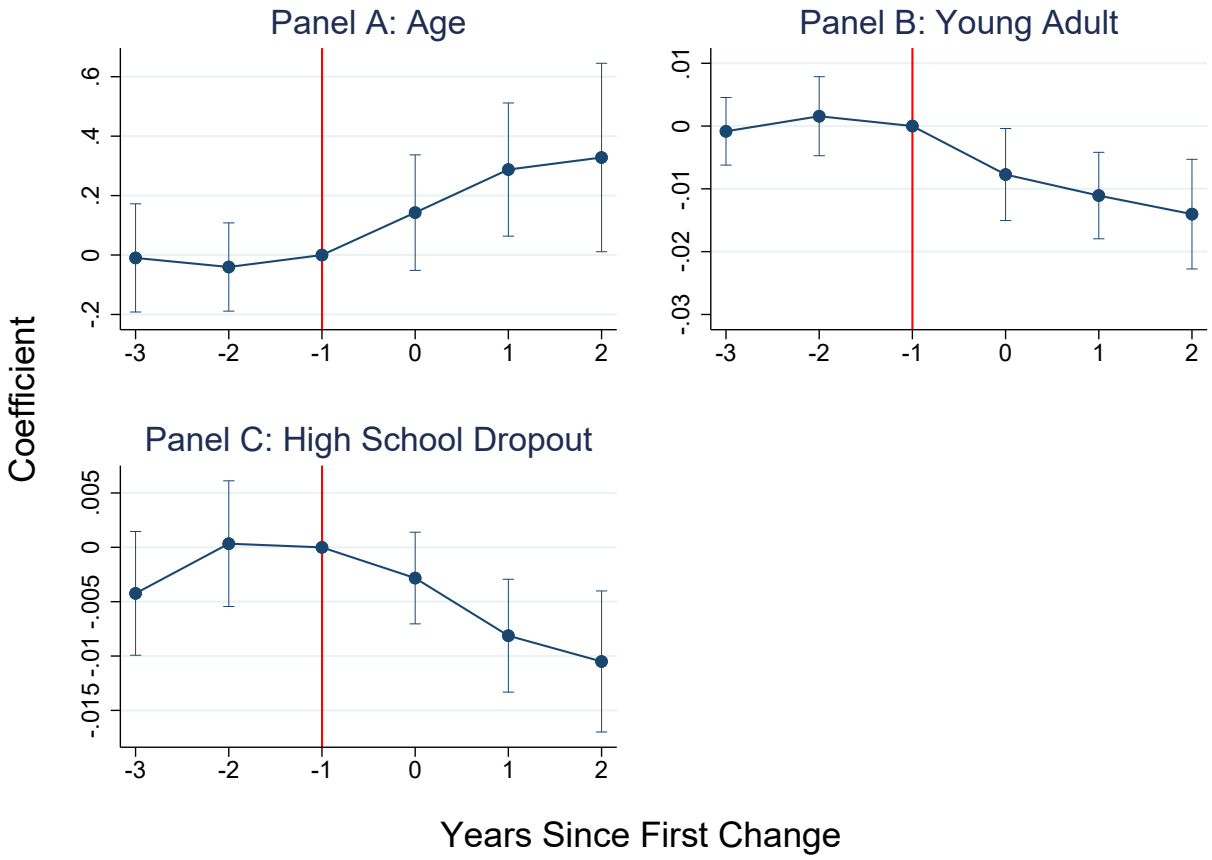

Figure 2: **Minimum Wage and Worker Skills (ACS) by Time Since First Increase**
Note: The figure reports results of a version of Equation (1), with the full set of controls described in the text, that allows for interactions between Increaser and each year before and after the first minimum wage hike. The omitted category is the year before the first change. We plot coefficients and 95% confidence bars, restricting the sample to low-wage occupations, using American Community Survey (ACS) data.

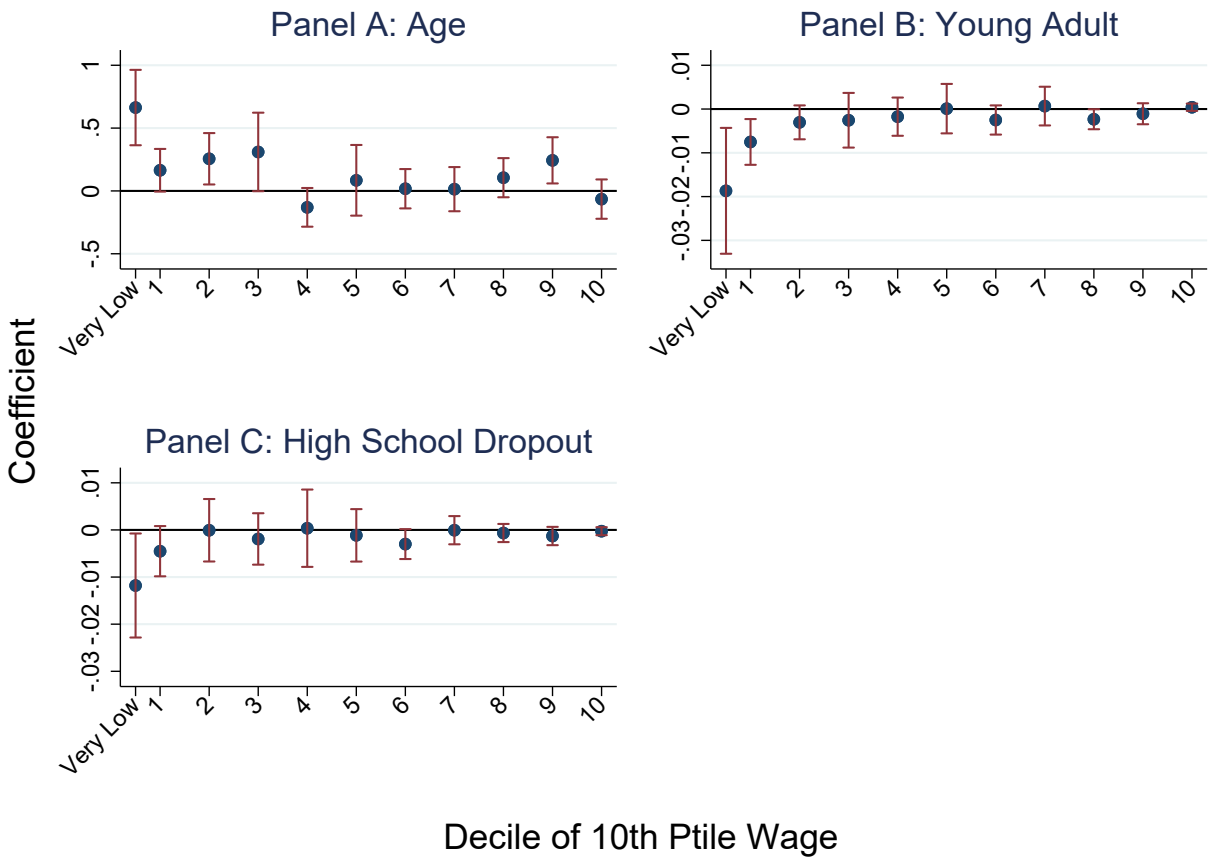

Figure 3: **Worker Skill Outcomes (ACS) by Occupation Group**
Note: The figure reports results of Equation (1), estimated separately by decile of their 10th percentile wage (the bottom decile is split into the lowest three occupations, "very low", and the remainder in the low category, "1"). We include full controls in all regressions and use American Community Survey (ACS) data. We report coefficients and 95% confidence bars.

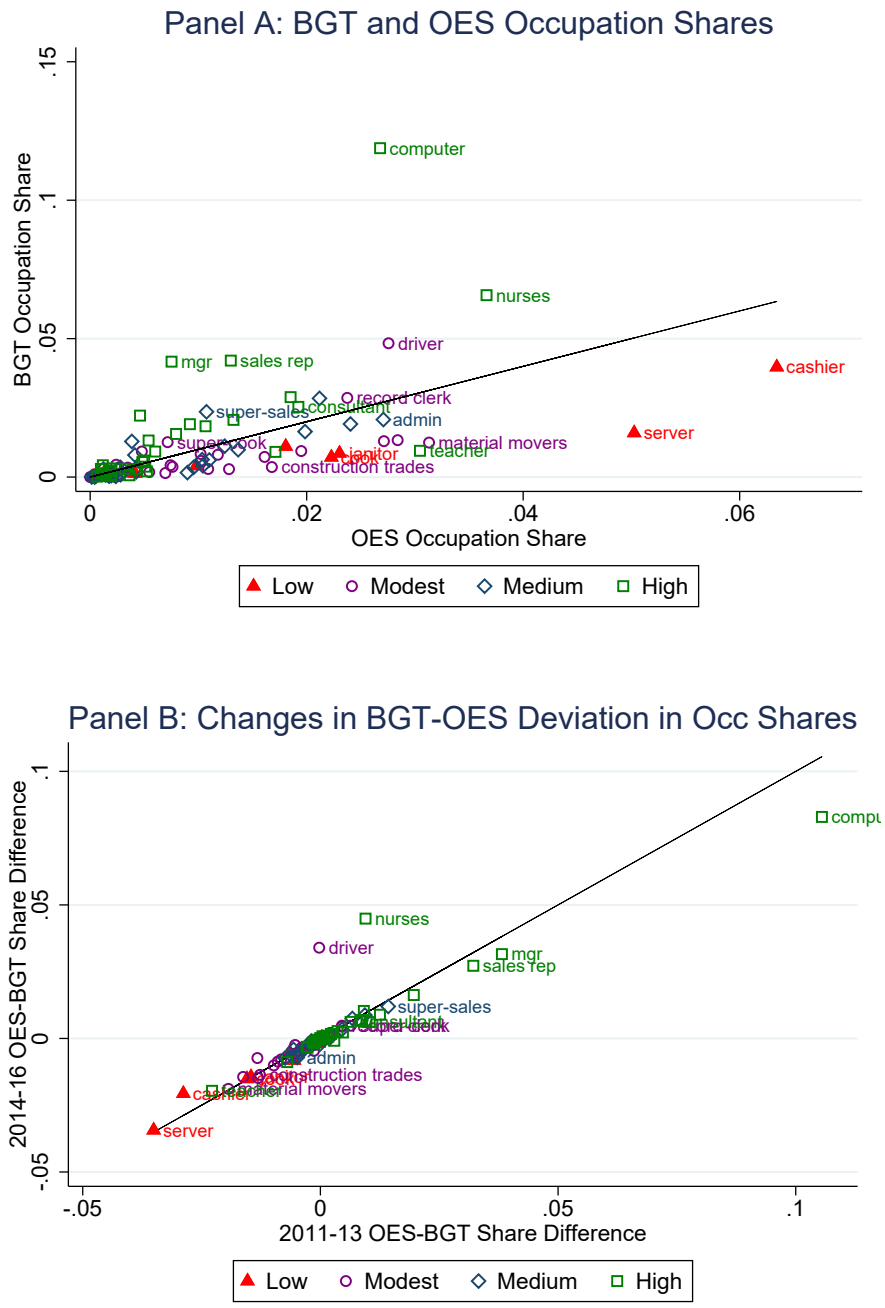

Figure 4: **Occupation Distributions in BGT and OES and Changes over Time**
Note: Figure A plots occupation shares in Burning Glass (BGT) on occupation shares in Occupational Employment Statistics (OES) for four-digit SOC occupations codes, averaged from 2011-2016. Figure B plots the average deviation between OES and BGT in 2014-16 occupation shares on the average deviation in 2014-16. Both figures include a 45 degree line.

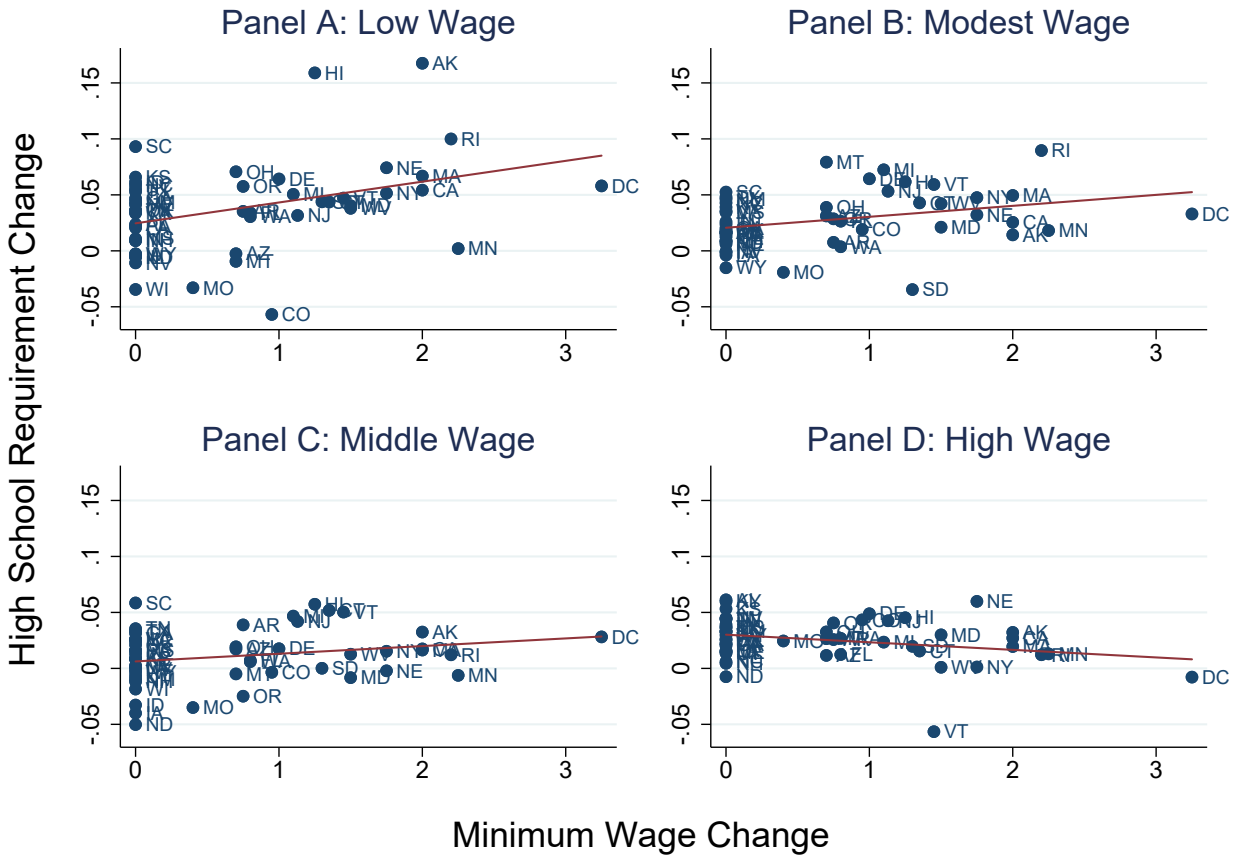

Figure 5: **Changes in High School Requirement (BGT) and Minimum Wage by State**
Note: The figure presents scatter plots of the state-level change in the prevalence of high school requirements from Burning Glass (BGT) on the state-level change in the minimum wage, separately by occupation group. The skill requirement change is the average difference between the period before a given state enacted its first minimum wage increase to the period from the first change onwards (see Table 1). Minimum wage changes on the x-axis are the total change for the state over the full time period. For states with no minimum wage change, we use the modal change date of statutory increasers, 2014. We group occupations based on their decile of the 10th percentile wage distribution, as measured in the 2006 Occupational Employment Statistics. "Low", "Modest", "Medium", and "High" wage occupations correspond to the 1st, 2-4, 5-7, and 8-10 deciles, respectively; see table 2.

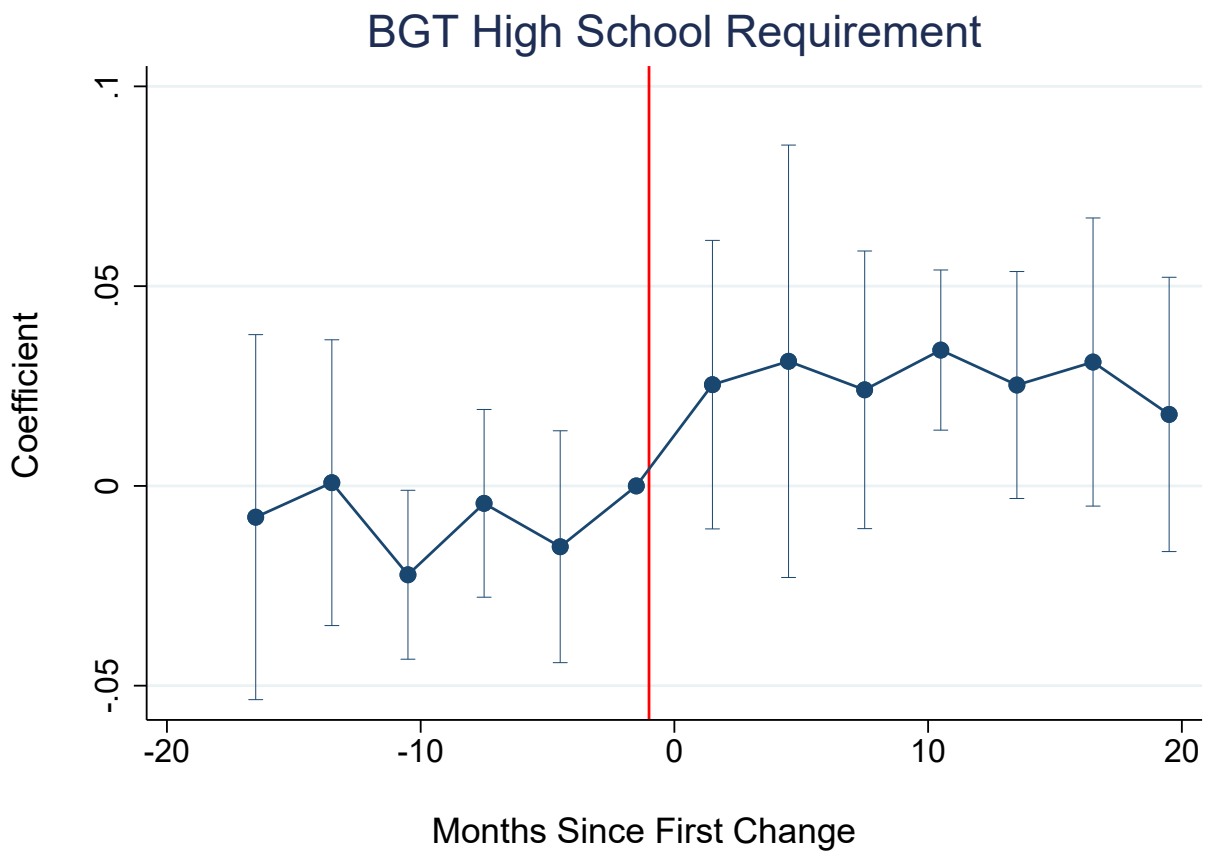

Figure 6: **Minimum Wage and Skill Requirements (BGT) by Time Since First Increase**
Note: The figure reports results of an expanded version of Equation (1) with full controls that allows for interactions between Increaser and each quarter before and after the first minimum wage hike. The omitted category is the quarter before the first change. We display point-estimates and 95% confidence bars for each quarter at their midpoint month in event time, restricting the sample to low-wage occupations in Burning Glass Technologies (BGT) data.

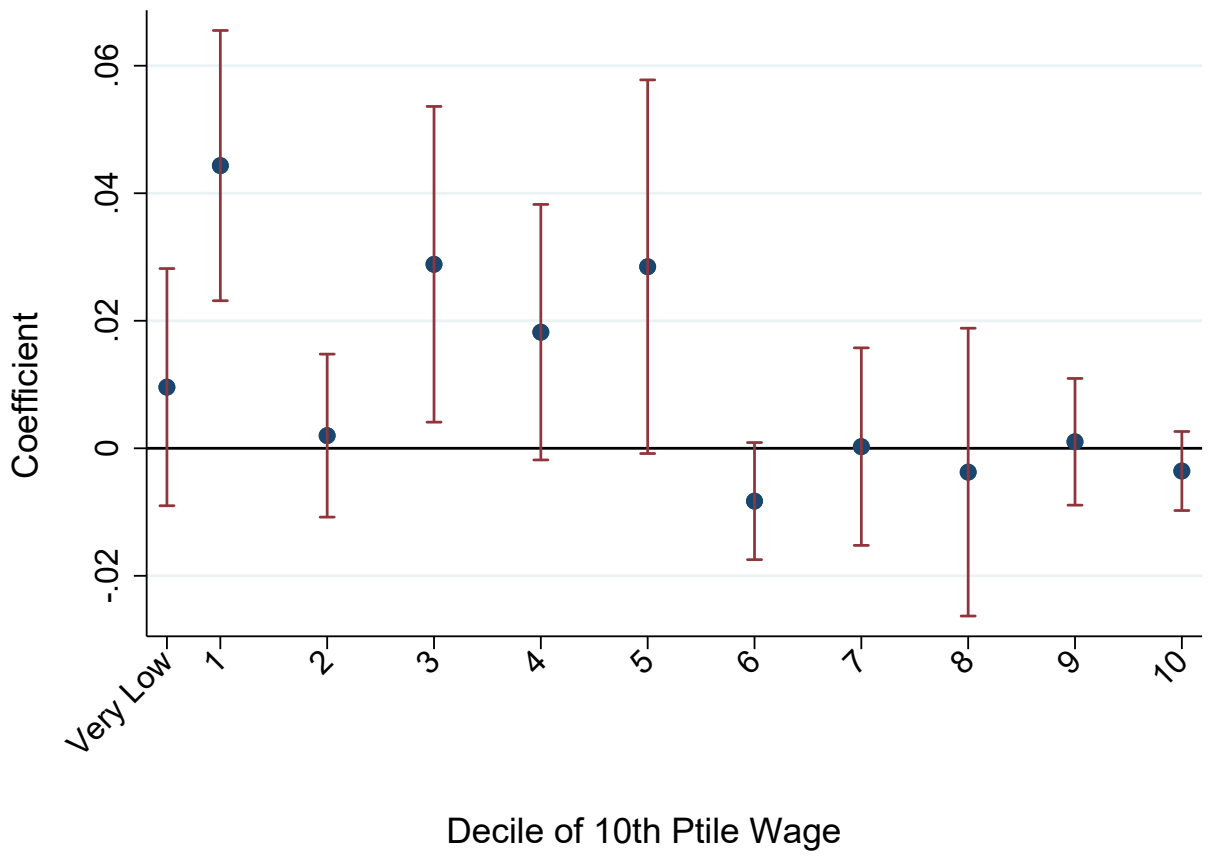

Figure 7: **High School Requirement (BGT) by Occupation Group**
Note: The figure reports results of equation (1), estimated separately by decile of their 10th percentile wage (the bottom decile is split into the lowest three occupations, "Very Low", and the remainder in the "Low" category). We include full controls in all regressions and use Burning Glass Technologies (BGT) data. We report coefficients and 95% confidence bars.

Table 1: **States with Minimum Wage Changes 2011-2016**

State	Total Change ($)	# Changes	Year of First Change
Alaska	2.00	2	2015
Arkansas	0.75	2	2015
California	2.00	2	2014
Connecticut	1.35	3	2014
Delaware	1.00	2	2014
District of Columbia	3.25	3	2014
Hawaii	1.25	2	2015
Maryland	1.50	2	2015
Massachusetts	2.00	2	2015
Michigan	1.10	2	2015
Minnesota	1.75	2	2015
Nebraska	1.75	2	2015
New Jersey	1.13	2	2014
New York	1.75	3	2014
Rhode Island	1.60	2	2015
South Dakota	1.30	2	2015
Vermont	0.87	2	2015
West Virginia	1.50	2	2015
Mean	1.68	2.22	2014

Note: The table summarizes minimum wage changes among states that had minimum wage increases through statutory legislation between 2011 and 2016. The first column lists the total change across the full time period. The second column lists the number of years within the time period where the July minimum wage of that year differed from the July minimum wage in the preceding year. The last column provides the year of the first minimum wage change within the time period. Means are based on American Community Survey sample weights.

Table 2: **Description of Low-Wage Occupations**

Occupation (SOC code)	10th Ptile Wage	Effective Min Wage Change		
		10th Ptile	25th Ptile	50th Ptile
Panel A: Low Wage Occupations				
Food and Beverage Serving (3530)	$5.85	$1.27	$0.87	$0.30
Other Food Prep/Serving (3590)	$6.00	$1.34	$0.95	$0.39
Entertainment Attendants (3930)	$6.04	$1.16	$0.64	$0.01
Other Personal Care/Service (3990)	$6.40	$0.62	$0.03	$0
Cooks and Food Prep (3520)	$6.41	$0.90	$0.34	$0
Retail Sales (4120)	$6.57	$1.05	$0.47	$0
Animal Care and Service (3920)	$6.65	$1.03	$0.38	$0
Building Cleaning/Pest Control (3720)	$6.66	$0.80	$0.18	$0
Personal Appearance (3950)	$6.71	$0.94	$0.29	$0
Tour and Travel Guides (3970)	$6.74	$0.45	$0.09	$0
Baggage Porters/Bellhops/Concierges (3960)	$6.79	$0.38	$0.02	$0
Textile/Apparel/Furnishing (5160)	$7.13	$0.89	$0.28	$0
Panel B: Aggregated Occupation Groups				
Low-Wage Occupations	$6.39	$1.01	$0.47	$0.08
Modest-Wage Occupations	$8.17	$0.18	$0.05	$0.02
Medium-Wage Occupations	$10.83	$0.01	$0	$0
High-Wage Occupations	$18.52	$0	$0	$0
All	$11.40	$0.22	$0.09	$0.02

Note: We group occupations based on their decile of the 10th percentile wage distribution, as measured in the 2006 Occupational Employment Statistics (OES). "Low" wage occupations correspond to the bottom decile, "Modest" to the 2-4th deciles, "Medium" to the 5-7th deciles, and 'High" to the 8-10th deciles. Panel A lists each 4-digit occupation in the "Low" group, and the 10th percentile wage of that occupation in 2006 (from OES). We also provide the "Effective Minimum Wage Change", which gives the mechanical amount that wages need to increase from their 2011-13 average level to comply with 2016 minimum wage levels. Specifically, for state-occupation pairs, we calculate the gap between the OES 2013 wage and the minimum wage in 2016 (or impute zero if wages in 2013 are already above the eventual minimum wage in 2016), then average across states using OES employment weights. Panel B summarizes these estimates for each occupation group. We choose 2013 as the benchmark year because OES data reflect 3-year rolling averages and thus our benchmark year represents the 2011-2013 period.

Table 3: **Summary Statistics**

Occupation Group	Low	Modest	Middle	High
Panel A: ACS Variables				
Age	35.47	39.43	41.58	42.86
	(14.07)	(13.11)	(12.21)	(11.51)
Young adult (16-21)	0.211	0.0900	0.0358	0.0126
	(0.408)	(0.286)	(0.186)	(0.112)
Older adult (50+)	0.218	0.276	0.310	0.328
	(0.413)	(0.447)	(0.462)	(0.469)
No High School Degree	0.175	0.126	0.0534	0.0146
	(0.380)	(0.332)	(0.225)	(0.120)
High School or Some College	0.721	0.730	0.678	0.333
	(0.448)	(0.444)	(0.467)	(0.471)
Observations	1224134	2188901	1832915	2660420
Panel B: BGT Variables				
Any Education Requirement	0.302	0.456	0.566	0.705
	(0.176)	(0.195)	(0.166)	(0.139)
HS Requirement	0.262	0.371	0.366	0.133
	(0.148)	(0.177)	(0.178)	(0.148)
College Requirement	0.0219	0.0611	0.135	0.400
	(0.0384)	(0.0983)	(0.147)	(0.222)
Any Experience Requirement	0.237	0.349	0.577	0.626
	(0.135)	(0.165)	(0.160)	(0.145)
Customer Service Requirement	0.490	0.399	0.469	0.371
	(0.330)	(0.242)	(0.248)	(0.223)
Non-Cognitive Skill Requirement	0.249	0.268	0.337	0.271
	(0.128)	(0.166)	(0.174)	(0.144)
Computer Requirement	0.0922	0.257	0.362	0.437
	(0.0872)	(0.190)	(0.197)	(0.210)
Cognitive Skill Requirement	0.135	0.204	0.306	0.416
	(0.0926)	(0.132)	(0.165)	(0.190)
English Requirement	0.0961	0.118	0.0712	0.0692
	(0.0919)	(0.107)	(0.0677)	(0.0776)
Occ-State-Date Cells	28526	53969	50829	68518
Number of Ads	5662223	6012438	5404719	10329025
Ads per Cell	198.5	111.4	106.3	150.7

Note: This table presents means and standard deviations (in parentheses) for key dependent variables, by occupation group. We group occupations based on their decile of the 10th percentile within-occupation wage distribution, as measured in the 2006 Occupational Employment Statistics. "Low", "Modest", "Medium", and "High" wage occupations correspond to the 1st, 2-4, 5-7, and 8-10 deciles, respectively. American Community Survey (ACS) variables are restricted to employed respondents and summarized using sample weights. Burning Glass (BGT) data on job vacancy postings are at the 4-digit occupation-state-date (year-month) level and summarized using OES state-occupation-year employment weights. Customer service, non-cognitive skill, computer, cognitive skill, and English requirements are defined in the manuscript; see Deming and Kahn (2018) for additional details.

Table 4: **Worker Skills (ACS) and Minimum Wages: Low Wage Occupations**

	Low Wage Occupations		
	(1)	(2)	(3)
Panel A:	Age		
Increaser*After	0.301***	0.259***	0.262***
	(0.0796)	(0.0741)	(0.0785)
Panel B:	Young Adult (16-21)		
Increaser*After	-0.00886***	-0.00814***	-0.00972***
	(0.00229)	(0.00226)	(0.00265)
Panel C:	Older Adult (50-64)		
Increaser*After	0.00648***	0.00552***	0.00554**
	(0.00231)	(0.00204)	(0.00232)
Panel D:	No High School Degree		
Increaser*After	-0.00622**	-0.00615**	-0.00589**
	(0.00293)	(0.00287)	(0.00270)
Panel E:	High School or Some College		
Increaser*After	0.00710*	0.00745*	0.00482*
	(0.00370)	(0.00375)	(0.00278)
Observations	1,224,134	1,224,132	1,224,132
Occ, State, and Year FE	Yes	Yes	Yes
Occ-by-Yr, Occ-by-State FE	No	Yes	Yes
Macroeconomic Controls	No	No	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. Each panel reports a different dependent variable for regressions of the form specified in equation 1. Observations are from the ACS 2011-16 waves, restricted to those age 16-64 who are employed in low-wage occupations (see table 2). "Increaser*After" is an indicator equalling one if the state has any minimum wage increase through statutory legislation AND the current year is on or after the first such increase. Macroeconomic controls are the log of personal income, a housing price index, the employment rate in the state-year, an indicator for whether an ACA Medicaid expansion is in effect in the state-year, the expansion indicator interacted with an after 2013 indicator, and the health insurance market concentration for providers to large and small firms. Standard errors are clustered at the state level. Regressions also include an Indexer*After interaction.

Table 5: **Minimum Wages and Employment (ACS), by Occupation Group**

Occupation Group	Low	Modest	Medium	High
		Wage Occupations		
	(1)	(2)	(3)	(4)
Panel A:	Employment Probability in the Population			
Increaser*After	0.00121*	-0.00275**	0.00134	0.000529
	(0.000714)	(0.00119)	(0.000954)	(0.00125)
Observations	11,936,824	11,936,824	11,936,824	11,936,824
Panel B:	Employment Share among the Employed			
Increaser*After	0.00159	-0.00387***	0.00189	0.000228
	(0.00103)	(0.00118)	(0.00126)	(0.00166)
Observations	7,939,968	7,939,968	7,939,968	7,939,968
Panel C:	Usual Hours Worked Conditional on Employment			
Increaser*After	-0.0683	-0.0408	-0.0614	-0.00539
	(0.110)	(0.0704)	(0.0707)	(0.0501)
Observations	1,224,134	2,188,901	1,832,915	2,660,420
Panel D:	Weeks Worked Conditional on Employment			
Increaser*After	0.196**	0.00504	0.00639	-0.0643**
	(0.0848)	(0.0665)	(0.0393)	(0.0281)
Observations	1,224,134	2,188,901	1,832,915	2,660,420
Full Controls	Yes	Yes	Yes	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. See Table 4. The table reports estimates of Equation (1). The dependent variable in panel A is an indicator equalling 1 if the individual is employed in the indicated occupation group and zero otherwise – column 1 is Low, column 2 modest, column 3 medium, column 4 high wage occupations (see table 2). It is estimated on the full American Community Survey sample (age 16-64). In panels B, C and D, the samples are restricted to employed individuals. Panel B estimates employment shares for the indicated occupation group, within the sample of employed. Panels C and D estimate hours and weeks worked conditional on employment in the indicated occupation group. Because the dependent variables in this table involve employment, we exclude the aggregate employment rate in the control set, as well as all controls involving occupation fixed effects, but include all other controls from column 4 of table 4. Regressions also include an Indexer*After interaction.

Table 6: **Minimum Wages and Labor Force Outcomes (ACS)**

Dependent Variable:	Employed			Out of the labor force		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A:			Overall			
Increaser*After	0.00333		0.000425	-0.000128		0.000532
	(0.00230)		(0.00187)	(0.000889)		(0.00121)
State, and Year FE	Yes		Yes	Yes		Yes
Macroeconomic Controls	No		Yes	No		Yes
Panel B:			by Age Group			
Increaser*After	-0.0258***	-0.00717	-0.00965**	0.0381***	0.00704**	0.00721**
	(0.00894)	(0.00440)	(0.00408)	(0.00887)	(0.00303)	(0.00307)
Increaser*After*Age 22-30	0.0302***	0.00870**	0.00864**	-0.0358***	-0.00595**	-0.00594**
	(0.00813)	(0.00403)	(0.00404)	(0.00839)	(0.00290)	(0.00290)
Increaser*After*Age 31-40	0.0339***	0.0128***	0.0128***	-0.0421***	-0.00807**	-0.00808**
	(0.00967)	(0.00422)	(0.00422)	(0.00995)	(0.00360)	(0.00360)
Increaser*After*Age 41-49	0.0304***	0.0130***	0.0132***	-0.0406***	-0.00837***	-0.00839***
	(0.00919)	(0.00322)	(0.00320)	(0.00935)	(0.00278)	(0.00278)
Increaser*After*Age 50+	0.0346***	0.00998**	0.0103***	-0.0495***	-0.00667**	-0.00669**
	(0.0110)	(0.00386)	(0.00383)	(0.0115)	(0.00317)	(0.00317)
State and Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Demo group interactions	No	Yes	Yes	No	Yes	Yes
Macroeconomics Controls	No	No	Yes	No	No	Yes
Observations	11,936,824	11,936,824	11,936,824	11,936,824	11,936,824	11,936,824

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. The table reports a version of equation 1 estimated on the full American Community Survey sample (age 16-64). The dependent variable is an indicator for whether the individual is employed (columns 1-3) or out of the labor force (columns 4-6). Columns 1 and 4 control for state and year fixed effects (we exclude occupation fixed effects because they are closely related to employment) and age group or education group main effects in panel B. Columns 2 and 5 include interactions between the age groups and the state and year fixed effects. Columns 3 abd 6 include the macroeconomic and health insurance controls listed in table 4 except the employment rate, again because it is closely related to the dependent variable. Regressions also include an Indexer*After interaction and, where applicable, interactions with age group.

Table 7: **BGT High School Requirements and Minimum Wages**

Low-Wage Occupations			
Dependent Variable	High School Diploma Requirement		
	(1)	(2)	(3)
Increaser*After	0.0180**	0.0183**	0.0335***
	(0.00727)	(0.00732)	(0.00739)
Occupation-state-date Cells	28,526	28,473	28,473
Occ, State, and Date FE	Yes	Yes	Yes
Occ-by-Date, Occ-by-Date FE	No	Yes	Yes
Macroeconomic Controls	No	No	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. We report results for regressions of the form specified in Equation 1, for occupation-state-date (month-year) cells in the 2011-2016 waves of Burning Glass Technologies (BGT) job vacancy data. Observations are restricted to ads posted in low-wage occupations (see Table 2). The dependent variable is the share of ads within the cell that have a high school diploma requirement. Observations are weighted by OES occupation-state-year employment. Macro controls are listed in table 4 notes. Regressions also include an Indexer*After interaction.

Table 8: **BGT High School Requirements and Minimum Wages**

Low-Wage Occupations				
Dependent Variable	High School Diploma Requirement			
	(1)	(2)	(3)	(4)
Panel A:	Low Wage Occupations			
Increaser*After	0.0335***	0.00998*	0.0120**	0.0112**
	(0.00729)	(0.00507)	(0.00589)	(0.00519)
Firm-Occ-State-date cells	912,505	912,505	906,290	906,054
Full Controls	Yes	Yes	Yes	Yes
Firm Fixed Effects	No	Yes	Yes	Yes
Firm-by-State FEs	No	No	Yes	Yes
Firm-by-Year FEs	No	No	No	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. See tables 4 and 7. Observations are at the firm-occupation-state-date level, restricted to low-wage occupations, for 2011-2016 Burning Glass Technologies (BGT) job vacancy data. The dependent variable is the share of ads within the cell that have a high school diploma requirement. Observations are weighted by the ad share within state-occupation-date times OES occupation-state-year employment. Macro controls are listed in table 4 notes. Regressions also include an Indexer*After interaction.

A Appendix Tables and Figures

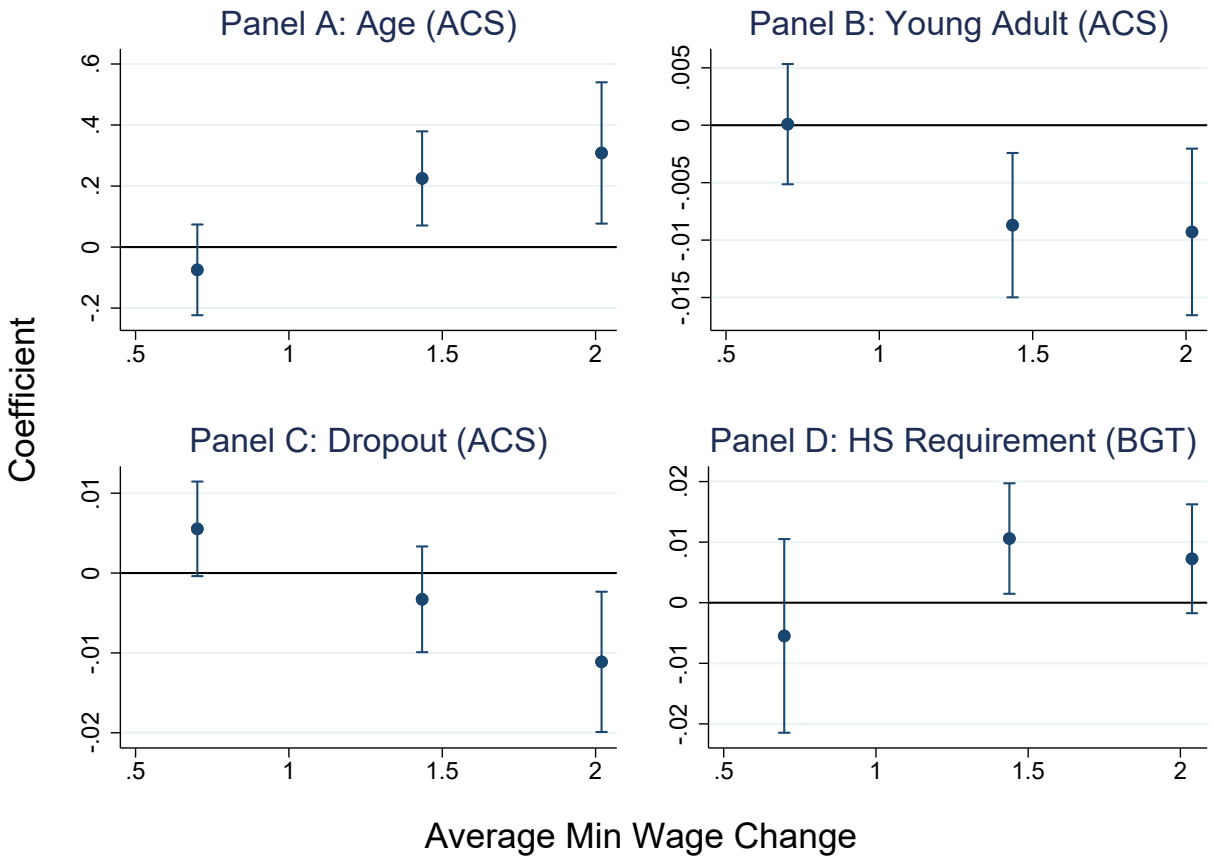

Figure A.1: **Outcomes by Size of Minimum Wage Increase**
Note: The figure reports results of Equation (1), allowing interactions between "after" and indicators for each tertile of state minimum wage increases over the full time period, with no change as the omitted category. We restrict to workers in low-wage occupations and estimate specifications with full controls, using American Community Survey (ACS) or Burning Glass Technologies (BGT) data as indicated. We plot coefficients for the interaction terms on the average minimum wage change in each tertile and 95% confidence bars.

Table A.1: **Worker Skills/Requirements and Minimum Wages: Robustness**

	Low Wage Occupations					
Specification:	Event			Linear		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A:	ACS – Age					
Increaser*After	0.301***	0.259***	0.262***			
	(0.0796)	(0.0741)	(0.0785)			
Indexer*After	-0.108	-0.0927	-0.105			
	(0.0809)	(0.0824)	(0.0786)			
Minimum Wage				0.218***	0.183***	0.160**
				(0.0635)	(0.0618)	(0.0707)
Panel B:	ACS – Young Adult (16-21)					
Increaser*After	-0.00886***	-0.00814***	-0.00972***			
	(0.00229)	(0.00226)	(0.00265)			
Indexer*After	0.00124	0.000746	0.00144			
	(0.00337)	(0.00345)	(0.00288)			
Minimum Wage				-0.00574***	-0.00512***	-0.00632***
				(0.00188)	(0.00189)	(0.00180)
Panel C:	ACS – Older Adult (50-64)					
Increaser*After	0.00648***	0.00552***	0.00554**			
	(0.00231)	(0.00204)	(0.00232)			
Indexer*After	-0.00426	-0.00410	-0.00471			
	(0.00338)	(0.00326)	(0.00295)			
Minimum Wage				0.00421**	0.00334**	0.00227
				(0.00163)	(0.00148)	(0.00174)
Panel D:	ACS – No High School Degree					
Increaser*After	-0.00622**	-0.00615**	-0.00589**			
	(0.00293)	(0.00287)	(0.00270)			
Indexer*After	0.00666**	0.00631**	0.00732***			
	(0.00299)	(0.00304)	(0.00269)			
Minimum Wage				-0.00373	-0.00352	-0.00282
				(0.00248)	(0.00240)	(0.00210)
Panel E:	ACS – High School or Some College					
Increaser*After	0.00710*	0.00745*	0.00482*			
	(0.00370)	(0.00375)	(0.00278)			
Indexer*After	-0.00247	-0.00210	-0.00294			
	(0.00338)	(0.00332)	(0.00292)			
Minimum Wage				0.00464	0.00473	0.00228
				(0.00295)	(0.00292)	(0.00212)
Observations	1,224,134	1,224,132	1,224,132	1,224,134	1,224,132	1,224,132
Panel F:	BGT – High School Diploma Requirement					
Increaser*After	0.0180**	0.0183**	0.0335***			
	(0.00727)	(0.00732)	(0.00739)			
Indexer*After	-0.00549	-0.00568	-0.00274			
	(0.0188)	(0.0184)	(0.0197)			
Minimum Wage				0.00935	0.00957	0.0145**
				(0.00651)	(0.00660)	(0.00661)
Occ-State-Date Cells	28,526	28,473	28,473	28,526	28,473	28,473
Occ, State, and Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Occ-by-Date, Occ-by-Date FE	No	Yes	Yes	No	Yes	Yes
Macroeconomic Controls	No	No	Yes	No	No	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. See tables 4 and 7. Panels A-E present ACS results; panel F presents BGT results. Both samples are restricted to low-wage occupations. Increaser is an indicator equaling 1 if the state had new legislation to increase their minimum wage during our sample period; indexer equals 1 if that state instead had minimum wage changes through inflation indexing; Minimum wage is the linear value for the state in July of the year.

Table A.2: **ACS Worker Skills and Minimum Wages: Low Wage Occupations**

	Low Wage Occupations		
	(1)	(2)	(3)
Panel A:	No High School Degree		
Increaser*After	-0.00622**	-0.00615**	-0.00589**
	(0.00293)	(0.00287)	(0.00270)
Panel B:	Ungraduated Teen (19 or younger)		
Increaser*After	-0.00466***	-0.00421**	-0.00602***
	(0.00168)	(0.00165)	(0.00142)
Panel C:	Adult Dropout (age>19)		
Increaser*After	-0.00156	-0.00194	0.000125
	(0.00311)	(0.00308)	(0.00199)
Observations	1,224,134	1,224,132	1,224,132
Occ, State, and Year FE	Yes	Yes	Yes
Occ-by-Yr, Occ-by-State FE	No	Yes	Yes
Macroeconomic Controls	No	No	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. See table 4. Panel A replicates Panel D of table 4. In panel B (C) the dependent variable is an indicator equalling 1 if the individual is age 19 or less (greater than 19) and lacks a high school diploma. The effect in panel A loads almost completely onto the panel B variable, implying that the high school diploma effect operates primarily via the age effects.

Table A.3: **Worker Skills/Requirements and Minimum Wages: Higher-Paying Occupations**

Occupation Group	Low	Modest	Medium	High
		Wage Occupations		
	(1)	(2)	(3)	(4)
Panel A:		ACS – Age		
Increaser*After	0.262***	0.107	0.0353	0.0571
	(0.0785)	(0.0715)	(0.0521)	(0.0610)
Panel B:		ACS – Young Adult (16-21)		
Increaser*After	-0.00972***	-0.00243	-0.000737	-0.000727*
	(0.00265)	(0.00177)	(0.00134)	(0.000425)
Panel C:		ACS – Older Adult (50-64)		
Increaser*After	0.00554**	0.00186	0.00327	0.00398*
	(0.00232)	(0.00223)	(0.00200)	(0.00220)
Panel D:		ACS – No High School Degree		
Increaser*After	-0.00589**	-0.000217	-0.00154	-0.000605*
	(0.00270)	(0.00305)	(0.00115)	(0.000344)
Panel E:		ACS – High School or Some College		
Increaser*After	0.00482*	-0.000428	0.00256	0.000996
	(0.00278)	(0.00262)	(0.00305)	(0.00202)
Observations	1,224,132	2,188,897	1,832,908	2,660,420
Panel F:		BGT – High School Diploma Requirement		
Increaser*After	0.0335***	0.0113*	0.00619	-0.00316
	(0.00739)	(0.00672)	(0.00581)	(0.00515)
Occ-State-Date Cells	28,473	53,860	50,592	68,343
Full Controls	Yes	Yes	Yes	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. Column 1 replicates the full controls (column 3) specification from tables 4 and 7 for low-wage occupations. Column 2 restricts to workers and ads in modest-wage occupations; column 3 restricts to medium-wage occupations; column 4 to high-wage (see Table 2 for definitions). Dependent variables and data set are indicated in the panel headings.

Table A.4: **ACS Worker Demographics and Minimum Wages**

Occupation Group	Low	Modest	Medium	High
		Wage Occupations		
	(1)	(2)	(3)	(4)
Panel A:		Black		
Increaser*After	0.00203	-0.00235	0.00298***	0.000926
	(0.00173)	(0.00225)	(0.00103)	(0.00134)
Panel B:		Hispanic		
Increaser*After	0.000224	0.00195	-0.000579	-0.000783
	(0.00249)	(0.00155)	(0.00250)	(0.00141)
Panel C:		Female		
Increaser*After	4.17e-05	-0.00119	0.000308	-0.00240
	(0.00292)	(0.00135)	(0.00199)	(0.00160)
Panel D:		Foreign Born		
Increaser*After	0.00378	0.00340	0.00208	-0.000723
	(0.00389)	(0.00295)	(0.00193)	(0.00180)
Panel E:		Migrated from Another State		
Increaser*After	-0.00188	-0.00156*	-0.000853	-0.00216**
	(0.00117)	(0.000905)	(0.000757)	(0.000994)
Observations	1,224,132	2,188,897	1,832,908	2,660,420
Full Controls	Yes	Yes	Yes	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. Column 1 restricts to workers employed in low-wage occupations; column 2 to modest-wage occupations; column 3 to medium-wage occupations; column 4 to high-wage (see table 2 for definitions). Outcomes are the share of worker employed in the indicated occupation group who belong to the group indicated in the panel heading. See Table 4.

Table A.5: **BGT Representativeness and sample restrictions**

	(1)	(2)	(3)
Panel A:	BGT-OES Occupation Share Deviation		
Increaser*After	0.00575***	-0.00168	-0.00173
	(0.00190)	(0.00109)	(0.00103)
Increaser*After*Modest	-0.00700***	0.00173*	0.00174*
	(0.00193)	(0.000939)	(0.000941)
Increaser*After*Medium	-0.00824***	0.00162	0.00162
	(0.00201)	(0.00111)	(0.00111)
Increaser*After*High	-0.00753**	0.00188	0.00188
	(0.00309)	(0.00148)	(0.00148)
Observations	10,808	10,764	10,764
Panel B:	In non-missing firm sample		
Increaser*After	0.0681***	0.0264	0.0406**
	(0.0184)	(0.0239)	(0.0191)
Increaser*After*Modest	-0.0541***	-0.0148	-0.0142
	(0.00841)	(0.0110)	(0.0109)
Increaser*After*Medium	-0.0684***	-0.0155	-0.0156
	(0.00732)	(0.0109)	(0.0108)
Increaser*After*High	-0.0775***	-0.0102	-0.00936
	(0.00862)	(0.0125)	(0.0123)
Observations	318,997	318,856	318,856
Panel C:	In regular low-wage employer sample		
Increaser*After	0.0409***	0.00436	0.0118
	(0.00976)	(0.0146)	(0.0110)
Increaser*After*Modest	-0.0468***	-0.00512	-0.00491
	(0.00859)	(0.00922)	(0.00926)
Increaser*After*Medium	-0.0442***	-0.00310	-0.00314
	(0.00979)	(0.0101)	(0.0101)
Increaser*After*High	-0.0557***	-0.00144	-0.00102
	(0.0114)	(0.0109)	(0.0108)
Observations	318,997	318,856	318,856
Occ, State, and Date FE	Yes	Yes	Yes
Occ-by-Date, Occ-by-Date FE	No	Yes	Yes
Macroeconomic Controls	No	No	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. In panel A the dependent variable is the BGT occupation ad share in the state-year minus the OES occupation employment share. Observations are occupation-state-years. OES data are from 2013 and 2016, which each represent three-year averages. BGT data are correspondingly averages from 2011-2013 and 2014-2016. The "after" variable and time-varying controls are also three-year averages. In panels B and C, observations are occupation-state-date (year-month) cells in BGT. Outcomes are the share of ads with a non-missing employer (panel B) or the share of ads by employers that regularly post in low-wage occupations (in at least 20 states and 20 months over our sample period) (panel C).

Table A.6: **BGT High School Requirement Robustness**

Dependent Variable	High School Diploma Requirement		
	Low-wage occupations		
	(1)	(2)	(3)
Panel A:	Preferred sample		
Increaser*After	0.0180**	0.0183**	0.0335***
	(0.00727)	(0.00732)	(0.00739)
Observations	28,526	28,473	28,473
Panel B:	Full sample		
Increaser*After	0.00673	0.00667	0.0217***
	(0.00895)	(0.00884)	(0.00705)
Observations	36,287	36,274	36,274
Panel C:	Non-Missing firm sample		
Increaser*After	0.00974	0.00963	0.0224***
	(0.00816)	(0.00825)	(0.00691)
Observations	33,181	33,153	33,153
Panel D:	Stronger low-wage employer restriction		
Increaser*After	0.0161**	0.0168**	0.0285***
	(0.00770)	(0.00801)	(0.00936)
Observations	25,503	25,481	25,481
Occ, State, and Date FE	Yes	Yes	Yes
Occ-by-Date, Occ-by-Date FE	No	Yes	Yes
Macroeconomic Controls	No	No	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. Table restricts to ads posted in low-wage occupations (see table 2 for definitions) and the dependent variable is the share of ads with a high school diploma requirement. Our preferred sample (panel A) restricts to ads with non-missing employers and further restricts to employers that post frequently in low-wage occupations (in at least 20 states and 20 months). Panel B imposes no restrictions. Panel C imposes only that ads have a non-missing firm. Panel D imposes a stronger restriction that employers must post in low-wage occupations in at least 40 states and 40 months. See table 7.

Table A.7: **BGT Skill Requirements and Minimum Wages**

Occupation Group	Low	Modest	Medium	High
		Wage Occupations		
	(1)	(2)	(3)	(4)
Panel A:		College Requirement		
Increaser*After	0.00126	-0.000251	0.00430	0.0116**
	(0.00190)	(0.00153)	(0.00335)	(0.00564)
Panel B:		Any Experience Requirement		
Increaser*After	0.00606	-0.0123	-0.00580	0.00676
	(0.00915)	(0.00800)	(0.00436)	(0.00610)
Panel C:		Customer Service Skill Requirement		
Increaser*After	0.0214***	0.00665	0.00207	-0.00204
	(0.00766)	(0.00427)	(0.00410)	(0.00633)
Panel D:		Non-Cognitive Skill Requirement		
Increaser*After	-0.00137	-0.000454	-0.00768	0.0134***
	(0.00572)	(0.00355)	(0.00600)	(0.00466)
Panel E:		English Requirement		
Increaser*After	0.000866	0.00216	-0.00335	-0.00727
	(0.00685)	(0.00598)	(0.00275)	(0.00709)
Panel F:		Computer Requirement		
Increaser*After	-0.00957**	0.00827	-0.00165	0.00688
	(0.00475)	(0.00538)	(0.00593)	(0.00483)
Panel G:		Cognitive Skill Requirement		
Increaser*After	-0.0152**	-0.00154	0.0114**	0.00458
	(0.00613)	(0.00419)	(0.00524)	(0.00354)
Occ-State-Date Cells	28,457	53,852	50,581	68,327
Full Controls	Yes	Yes	Yes	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. Column 1 restricts to ads posted in low-wage occupations; column 2 to modest-wage occupations; column 3 to medium-wage occupations; column 4 to high-wage (see table 2 for definitions). Outcomes are the share of ads for the indicated occupation group that require the skill indicated in the panel heading using Burning Glass Technologies (BGT) data. Customer service, non-cognitive skill, computer, cognitive skill, and English requirements are defined in the manuscript; see Deming and Kahn (2018) for additional details.

Table A.8: **BG Effects on Number of Vacancies**

Occupation Group	Low	Modest	Medium	High
		Wage Occupations		
	(1)	(2)	(3)	(4)
Panel A:		Vacancy Shares		
Statutory*After	-0.00806	-0.00341	0.00159	0.00989
	(0.00615)	(0.00396)	(0.00274)	(0.00643)
Indexer*After	-0.00404	-0.000404	-0.000382	0.00483
	(0.00654)	(0.00412)	(0.00264)	(0.00801)
Observations	14,688	14,688	14,688	14,688
Panel B:		Number of Vacancies (mean = 1899)		
Statutory*After	-226.4	-284.7	-111.4	-62.78
	(260.0)	(271.6)	(167.2)	(358.0)
Indexer*After	-113.4	-140.1	-86.32	-153.9
	(310.8)	(270.4)	(173.9)	(287.1)
Observations	3,672	3,672	3,672	3,672
Panel C:		Log(Vacancies) (mean = 7.0)		
Statutory*After	-0.0341	-0.0149	0.0249	0.0248
	(0.0457)	(0.0522)	(0.0412)	(0.0472)
Indexer*After	-0.0183	0.00136	-0.00317	0.0283
	(0.0371)	(0.0381)	(0.0498)	(0.0666)
Observations	3,672	3,672	3,672	3,672
Full Controls	Yes	Yes	Yes	Yes

Note: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 levels respectively. Observations are at the occupation group-state-date. Full controls include state and date fixed effects as well as macroeconomic and ACA condrols (see Table 4). The dependent variable in panel A is an indicator equalling 1 if the ad was for the indicated occupation group – column 1 is Low, column 2 modest, column 3 medium, column 4 high wage occupations (see table 2). We weight observations in this panel by the number of ads posted so results can be interpreted as the share of ads falling in an indicated occupation group. Panels B and C restrict observations to the indicated occupation group and use as the dependent variable the number of ads posted and the log postings, respectively. These regressions are unweighted but results are similar when we instead weight by state-occupation group annual employment.