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Who wins in an energy boom? Evidence from wage rates and housing

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Who Wins in an Energy Boom? Evidence from Wage Rates and Housing

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ABSTRACT

This paper presents evidence on the distributional effects of energy extraction by examining the recent U.S. energy boom. The boom increased local wage rates in almost every major occupational category. The increase occurred regardless of whether the occupation experienced a corresponding change in employment, suggesting a more competitive labor market that benefited local workers. Local housing values and rental prices both increased, thereby benefiting landowners. For renters, the increase in prices was completely offset by a contemporaneous increase in income. The results indicate that bans on drilling have negative monetary consequences for a large share of local residents.

JEL Classification Codes: J23, Q33, R31

Key Words: oil, natural gas; hydraulic fracturing; fracking; resource extraction; labor market effects; resource curse; Dutch disease; wage rates; housing values; rental prices

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Recent changes in the drilling technologies and practices have had a dramatic impact on energy development in the United States. Hydraulic fracturing, or “fracking”, in which water, sand, and chemicals are injected into shale reserves to allow for extraction of natural gas and oil, has led to a large increase in U.S. production of gas and oil. In addition to having trillions of dollars in direct value, shale gas and oil withdrawals may reduce domestic energy prices thereby leading to increases in consumer surplus and enhanced growth in other sectors of the economy (Hausman and Kellogg 2015; Mason, Muehlenbachs, and Olmstead 2015).

While fracking has led to substantial economic benefits, fracking has also been linked to various types of social damages, including potential contamination of water systems (Osborn et al., 2011; Environmental Protection Agency, 2011; Olmstead et al., 2013), increased depreciation and congestion of local infrastructure (U.S. Government Accountability Office 2012), and problems associated with rapid in-migration, such as increased crime rates (James and Smith, 2014). Because of the potential damages associated with fracking, policymakers have considered regulating drilling through moratoria, taxes, or restrictions on drilling techniques and materials. For example, citing environmental and health concerns, Governor Andrew Cuomo announced a ban on fracking in New York State at the end of 2014 despite the fact that the state overlays the Marcellus Shale, which contains large and valuable gas reserves. Municipalities in other states that permit fracking, such as Texas and Pennsylvania, have used local ordinances and zoning laws to ban or regulate drilling.

Debates about drilling policies center, at least in part, on how energy booms affect the local economy because communities are more likely to support drilling when more individuals in the community benefit from it. Labor market effects are often the primary focus of these debates. For example, in the 2014 Pennsylvania Gubernatorial race, Republican candidate Tom Corbett

opposed a 5 percent severance tax placed on natural gas production that was proposed by his opponent. Corbett justified his opposition by describing the benefits of shale development to local workers.¹

In this paper, I attempt to inform debates on drilling policies—which often have national implications—by examining how the recent U.S. energy boom has affected local economies. There are a wide variety of economic outcomes that can be influenced by an energy boom, and I focus on wage rates, housing values, and rental prices. Wage rates are important because they represent the primary way in which workers who are employed and unwilling to switch occupations can be affected by the boom. Housing values are important because land appreciation is a direct avenue by which energy booms can benefit local landowners. Rental prices are another avenue by which booms can benefit landowners and, perhaps more importantly, provide a measure of local price inflation. Local inflation can undermine other monetary gains and potentially turn the boom into a loss for those who are unable to tap into its benefits. Part of the reason all three outcomes are important is because each one represents a type of price, and price effects can easily affect residents who are not directly connected to the energy boom.²

The analysis is based on a difference-in-differences empirical framework and annual panel data on energy production, wage rates, and housing from nonmetropolitan regions in the United States. To preview the main results, I estimate that the recent U.S. energy boom increased wage rates in local economies in boom areas by 7 percent between 2006 and 2014. The increase

¹ The effects of fracking on local communities have also been a part of national-level debates, such as the current Democratic Presidential Primary. At the 2014 National Clean Energy Summit, Hillary Clinton emphasized the possibility of natural gas as a bridge to a clean energy economy and noted that expanding production leads to job creation. Bernie Sanders, in contrast, has supported a ban on fracking.

² For example, effects on nonprice outcomes, such as income per capita, may reflect changes experienced by a smaller share of the population, such as those owning parcels overlaying resource endowments.

occurred across almost all occupations regardless of whether the occupation experienced a contemporaneous increase in employment, suggesting that the overall labor market became more competitive in boom areas, thereby benefiting local workers.³ The wage rate effects were largest in percentage terms in the lower parts of the wage rate distribution. With respect to the housing market, I estimate that the boom increased housing values in boom areas by 12 percent between 2007 and 2012. Rental rates increased by an estimated 5 percent over the same time period. The increase in rental prices was small in comparison to other monetary gains. Additionally, there is no evidence that the boom increased the cost of rent when measured as a percentage of household income. In sum, the results indicate that there are many monetary “winners” from energy development in local communities and very few losers. An implication of the results is that bans on drilling have negative monetary consequences for a large share of local residents.

This paper contributes to the literature on the local effects of energy booms. This literature has predominantly focused on income and employment and has generally documented positive effects (Allcott and Keniston 2014; Black, McKinnish, and Sanders 2005; Fetzer 2014; Feyrer, Mansur, and Sacerdote 2015; Jacobsen and Parker 2016; James and Aadland 2011; Maniloff and Mastromonaco 2014; Marchand 2012; Michaels 2011; Papyrakis and Gerlagh 2007; Weber 2012).⁴ Wage rates, housing values, and rental prices have been substantially less studied.

With respect to wage rates, the most closely related studies are those that examine earnings per worker (Maniloff and Mastromonaco, 2014, Allcott and Keniston 2014, Marchand,

³The increase in wage rates in occupations that did not experience a contemporaneous increase in employment also suggests that the increase in wage rates was caused by higher pay rates as opposed to changes in the composition of specific occupations within each major occupational category.

⁴Jacobsen and Parker (2016) find that booms have contemporaneous positive effects on income per capita but also lead to reductions in incomes per capita in the postboom economy. The decline in incomes is more than offset by the benefits of the boom under reasonable discounting assumptions.

2012, Black et al., 2005).⁵ These studies, which find that booms lead to increases in earnings per worker, are not sufficient to establish that wage rates change because earnings per worker can adjust either through changes in the wage rate paid to employees or in the number of hours worked by the employee.⁶ In addition to directly evaluating wage rates, I also provide the first study to my knowledge that examines how the labor market effects of energy booms vary across occupations and across segments of the wage rate distribution, which provides a more detailed depiction of the distributional effects of energy booms.

With respect to housing, this paper contributes to a recent literature that has documented mixed evidence on the effect of the shale boom on housing values. On the negative side, Muehlenbachs, Spiller, and Timmins (2015) find that shale gas development had a negative effect on groundwater-dependent homes in Pennsylvania, and Gopalakrishnan and Klaiber (2014) find that shale extraction had a negative effect on housing values in Washington County, PA.⁷ On the positive side, Weber, Burnett, and Xiarchos (2015) find evidence that the shale boom increased housing values in zip codes with shale endowments in northeastern Texas, and Boslett, Guilfoos, and Lang (2016) find that the moratorium on shale drilling in New York State decreased home values, indicating a positive relationship between drilling and home values. I attempt to provide more general evidence on the relationship between shale development and

⁵ Using the Current Population Survey, Alcott and Keniston (2014) provide some evidence on whether wage rates have increased as a result of the oil and gas extraction; however, their empirical setting is not as well-suited to detect changes in local wage rates as the present paper because their treatment variable is recorded at the state-level due to the limited geographic identifiers included in the Current Population Survey. Unlike the present paper, they fail to show a significant relationship between resource abundance and wage rates during the modern energy boom.

⁶ Changes in wage rates will have a stronger effect on worker welfare because, unlike changes driven by increases in the number of hours worked, changes in wage rates are not accompanied by reduced leisure.

⁷ While not as closely related to the recent U.S. energy boom, Boxall, Chan, and McMillan (2005) also present evidence that supports a negative relationship. They find that housing values are negatively correlated with sour gas wells and flaring oil batteries in Central Alberta, Canada.

housing values by studying the phenomenon in a national geographic setting. I also add to the literature by examining the effect of shale gas on rental prices and by examining the housing effects in an empirical setting where they can be directly compared to the labor market effects.

The remainder of the paper proceeds as follows. The next section provides background information on the U.S. energy boom as well as a conceptual discussion of the manner in which the energy boom may affect local economies. After that, I describe the various data sources and present some descriptive statistics to characterize the empirical setting. I then describe and implement a difference-in-differences empirical framework. I conclude the paper with a discussion of the implications of the findings.

THE U.S. ENERGY BOOM

The recent U.S. energy boom has primarily been facilitated by advances in technology related to hydraulic fracturing, or “fracking.” Fracking involves high-pressure injections of liquid mixtures into geologic formations containing oil and gas reserves, such as shale. The pressure creates fissures that allow for the extraction of previously inaccessible reserves. Fracking was invented in 1947, but recent innovations in drilling techniques—most notably horizontal drilling—have made fracking more economically viable.

Figure 1 displays national trends in production of natural gas and oil in the United States. Production began to increase dramatically in the latter half of the 2000s and has continued to surge through 2014. The dashed lines in Figure 1 represent oil and gas production from shale

resources. The increase in extraction from shale explains nearly all of the recent increase in gas and oil production.⁸

In order to motivate the empirical analysis, it is worth briefly discussing how an energy boom might affect local economies in areas that experience surges in energy production.⁹ In general, increases in prospecting, drilling, and associated operations in a boom area are expected to lead to an immediate increase in employment in the extractive industry as well as connected industries, such as construction and transportation. Employment may also increase if the boom lowers local energy prices thereby attracting more industrial activity (Kahn and Mansur 2013). The increase in employment will lead to increases in in-migration and daily visitors (i.e. commuters) and increased demand for local goods and services. Employment will increase in the sectors providing local goods and services as well. Local incomes are expected to increase due to royalty payments and potentially increases in earnings, if wage rates rise or if employees work longer hours. Increases in local incomes will reinforce the increase in demand for local goods and services.

With respect to wage rates, the increase in the demand for labor is expected to increase wage rates unless migration is sufficient to create an offsetting increase in the labor supply.¹⁰ If

⁸ For Figure 1, overall gas and oil production levels were obtained from the U.S. Energy Information Administration (2015a), which also reports data on shale gas withdrawals but not oil withdrawals. For shale oil, data on extraction were obtained from USEIA (2015B), which reports information on withdrawals from the seven most prolific shale regions (Bakken, Niobrara, Eagle Ford, Permian, Haynesville, Utica, and Marcellus).

⁹ The purpose of this section is to provide a brief description of the most straightforward manner in which an energy boom will affect local economies, and I mostly focus on direct and positive effects. There are two substantial literatures on ways in which resources, often indirectly, can harm economies. Models of “Dutch Disease” (e.g., Cordon and Neary 1982) show that resource booms can harm open economies by creating a contraction in the tradable sector due to increases in local factor prices. The literature on the “Natural Resource Curse” (e.g., Sachs and Warner 1995, 1999, and 2001) similarly argues that resource abundance can harm economies, especially in the case of weak institutions (see Deacon [2011] and van der Ploeg [2011] for reviews). Empirical evidence related to the resource curse and Dutch Disease, which has typically been evaluated at that national level, is mixed.

¹⁰ Firms will be able to pay more for labor without operating at a loss if they experience a contemporaneous increase in demand. For locally traded goods, firms will be able to continue operating without a loss by passing costs

the costs of relocating are not zero, then the change in the labor supply will not be sufficient to offset the increase in demand and wage rates will increase. The change in labor supply will be substantially short of what is required to offset the increase in demand if prospective employees believe the increase in labor demand will be short-lived, as is often the case with energy booms. If migration is limited, wage rates will increase in any occupation in which at least some of the individuals in the occupation have skill sets that allow them to compete for positions in other occupations.

With respect to housing, the increased demand for housing from migrants is expected to provide upward pressure on both housing values and rental prices.¹¹ The royalty rates from extraction will provide further upward pressure on housing values. In contrast, disamenities from extraction, such as environmental degradation, will provide downward pressure.¹² The net effect of these competing forces is unclear.

In the subsequent analysis, I empirically examine whether the scenarios described above unfolded. While I examine some broad economic variables (e.g., employment and income per capita), I focus especially on outcomes related to wage rates and housing because they play a key role in the distributional effects of the energy boom and because there is generally more uncertainty about the effect of the boom for these outcomes.

on to customers. Firms may also choose to operate at a loss in the short term if they believe the boom will be short-lived and there are substantial start-up and shut-down costs.

¹¹ In addition to migration induced by employment opportunities, demand for housing may also increase because booms expand the tax base from producing wells thereby lowering tax rates and increasing the funds available for public goods (Weber, Burnett, and Xiarchos 2016).

¹² A substantial literature has shown that “locally undesirable land uses” are often associated with decreases in property values (Davis 2004, 2011; Gamper-Rabindran and Timmins 2013; Greenstone and Gallagher 2008; Mastromonaco 2015; Muehlenbachs, Spiller, and Timmins 2015; Sanders 2012).

DATA AND DESCRIPTIVE STATISTICS

County-level data on annual oil and gas withdrawals were obtained from the U.S. Department of Agriculture's (USDA) Economic Research Service. The data, which were published in 2014 and for which an update is not planned, represent the first time that nationwide data on annual production have been available at the county level. The data are available from 2000 to 2011. Oil production is measured in barrels and natural gas production is measured in metric cubic feet (Mcf). The withdrawal amounts were also converted to a joint production variable measured in dollars using the average price for natural gas and oil over the sample period (\$5.80 per Mcf and \$57.90 per barrel).¹³

Data on labor market outcomes were obtained from the Bureau of Labor Statistics' Occupational Employment Statistics (OES) program. The key feature of the OES data is that, unlike alternative sources such as the Bureau of Economic Analysis' Regional Economic Accounts, the data include information on hourly wage rates. For hourly workers, wage rates are based on their hourly wages, whereas for salaried workers' wage rates are based on their salaries divided by the number of hours worked annually.¹⁴ The data include information on the mean hourly wage rate and the hourly wage rate of the first decile, first quartile, median, third quartile, and ninth decile of the wage rate distribution. Information on all measurements is available overall and by 22 major occupational categories.¹⁵ The data also include information on

¹³ The conversion to dollars follows a conversion procedure described in the technical documents accompanying the USDA dataset. An alternative procedure is to convert the data to dollars by multiplying the production values times the average annual prices, as opposed to the average price over the entire sample period. The benefit of using average prices is that it allows for the oil and gas variables to be combined into a single variable while still allowing changes in the new variable to be driven by changes in extraction patterns, as opposed to price fluctuations.

¹⁴ The data do not include information on compensation for self-employed individuals.

¹⁵ OES data are based on estimates computed from a semiannual mail survey of nonfarm establishments. As such, the OES variables, like most BLS variables, are measured with error. Because the OES variables are

employment levels for each occupational category. The OES data are available annually for metropolitan and nonmetropolitan areas (NMAs) and I limit the analysis to NMAs because energy extraction is unlikely to have a substantial direct effect on metropolitan economies.

County-level data on housing values and rental prices were acquired from five-year estimates from the American Community Survey (ACS) and the 2000 Decennial Census.¹⁶ The ACS variables include median rental price, median value of owner-occupied housing, median rent as a percentage of household income, and the number of housing units.¹⁷ All values are based on five-year estimates using data from the five years up to and including the year in which they are labeled. Five-year estimates are available for 2009–2014, and I code each five-year estimate based on the middle year from the period from when the data were collected (i.e., the data from the 2009 data set is coded to 2007) because the data effectively approximate a rolling average. I discuss this issue in further detail later in the next section. Variables from the 2000 Decennial Census include the median value of owner-occupied housing and the number of housing units. These variables can be identically compared across the census and the ACS. For median gross rent and median rent as a percentage of income, comparisons across the ACS and Census cannot be made.¹⁸

dependent variables in the upcoming regression, the measurement error should lead to larger standard errors, but not biased estimates. Similar logic applies to the variables from the American Community Survey and the Regional Economic Accounts, which I discuss later in this section.

¹⁶ the ACS is an ongoing survey that the census uses to compute five-year, three-year, and one-year estimates. The three-year and one-year estimates cannot be used because they do not include most rural counties.

¹⁷ All rent variables are based on gross rents, which include the estimated monthly cost of utilities and fuels. The use of gross rent eliminates variation in rental prices driven by variation in whether utilities and fuels are included in the rental payments. Median rent as a percentage of household income reports the median value for rental households based on individual responses for income and rental prices (i.e., it is not calculated based on aggregated median rent and income levels).

¹⁸ See the ACS/Census Table comparison page at www.census.gov.

Annual data on incomes per capita, earnings per capita, and population for each U.S. county from 2001 to 2013 were acquired from the Bureau of Economic Analysis' (BEA) Regional Economic Accounts (REA). The BEA data have been used in other studies of energy booms that focus predominantly on income and employment effects (e.g., Jacobsen and Parker 2016).

The OES data are reported by NMA, which represent combinations of nonmetropolitan counties. An NMA includes about 12 counties on average, though there is substantial variation.¹⁹ To merge all data sets, I aggregate the county-level datasets to the NMA level using the NMA-county crosswalk provided in the OES data.²⁰ I limit the analysis to the continental United States, excluding the state of Virginia.²¹ I drop nine counties that are listed in multiple NMAs. I also drop NMAs for which the composition of counties changed over the course of the sample. These drops result in the exclusion of 7 out of 160 NMAs. Figure 4, which I discuss later in more detail, presents a map of all NMAs in the data.

The combined data set is comprised of a panel dataset at the NMA-year level. Most variables are reported for only a subset of the years. In particular, the OES wage data are only available from 2006–2014, the oil and gas data are only available through 2011, and the housing data are available for 2000 and 2007–2012. The BEA population and economic data are only available through 2013. Regardless, as I will discuss when describing the methodology, the combined dataset still allows for an examination of the recent effects of the energy boom.

¹⁹ NMAs in states where the average county is geographically larger are typically comprised of fewer counties.

²⁰ Population and all oil and gas variables are aggregated as an unweighted summation. Income per capita, net earnings per capita, median rental price, and median value of owner-occupied housing are aggregated using a population-weighted mean.

²¹ Virginia is dropped because the BLS and the census code subregions with Virginia differently. The census treats each Virginia township as a distinct region in county data sets whereas the BLS does not. The BLS coding is used in the OES data, whereas the census coding is used for the USDA data.

I generate several variables, the foremost of which is an indicator for a “boom” area. I define boom NMAs as NMAs in which annual extractions of oil and gas were at least \$500 million greater in 2011 than in 2006. The year 2006 was chosen because it is the first year for which OES data are available for NMAs, and 2011 was chosen because it is the last year that oil and gas data are available.²² The \$500 million cut point results in 17 of 160 NMAs being classified as boom areas, as can be seen in Figure 2, which presents a histogram of the change in oil and gas revenues across NMAs. The threshold for a boom area was set at \$500 million because it limits the “treatment” areas to those that have had large increases in energy extraction, yet still provides a sufficient number of treatment observations for adequate statistical power. As I will show in the next section, the results are robust to adjustments in the threshold used to define boom areas.²³ In addition to generating a boom variable, I also generate indicator variables for nonboom regions with some production of gas and oil between 2006 and 2011 and zero production between 2006 and 2011. I label these variables as “some-production” and “zero-production,” respectively.

Figure 3 presents information on trends in gas and oil extraction for boom and some-production areas. Boom areas have a relatively steady production trend leading up to the mid-2000s, at which point production begins to increase rapidly and nearly doubles by 2011. In some-production areas, production is level or very slightly declining throughout the sample period.

²² The selection of boom areas is extremely similar if the change from 2000 to 2011 in oil and gas production is used to define boom areas. The only difference is that two NMAs—Eastern Montana and Eastern & Southern Colorado—are also classified as boom areas.

²³ Binary measures of booms regions are common in the literature (Black, McKinnish, and Sanders 2005; Jacobsen and Parker 2016; Marchand 2012; Weber 2012) because they enable a transparent, graphical comparisons of boom and nonboom areas. A continuous measure of productions requires a broad set of assumptions about temporal lags and functional forms. The purpose of the present paper is not to provide precise parameters of how each well drilled or barrel extracted leads to changes in wage rates or housing prices, because that relationship likely depends on many situation-specific factors. Rather, the purpose is to provide a general characterization of the type of effects that are likely to be experienced locally during an energy boom.

Figure 4 presents a map of all NMAs. Boom areas are represented by the dark-blue regions and some-production areas are represented by the light-blue regions. The gray areas had zero production over 2000–2011. The white areas are metropolitan regions or areas that have been dropped from the analysis for reasons described previously. The boom areas are located near prominent shale plays and basins, including the Bakken in western North Dakota; the Niobrara in Wyoming, Colorado, and Utah; the Eagle Ford and Permian in Texas; the Haynesville near western Louisiana; and the Utica and Marcellus near the northern Appalachians. “Some-production” areas are generally located near boom areas and areas with “zero-production” areas are located further away from boom areas.

Summary statistics for oil and gas variables, major economic variables, and housing variables are presented in Table 1. The varying number of observations across variables primarily reflects the difference in the years spanned by the original dataset. About 10 percent of areas are boom areas, 40 percent are some-production areas, and 50 percent have had zero production. The typical NMA has a population of about 300,000, income per capita of \$35,000, and net earnings per capita of \$21,000. Average median home value is a bit over \$150,000. Average median rent is about \$700/month and about 30 percent of household income. In the typical NMA, there are about 150,000 housing units.

Table 2 presents summary statistics for wage variables. The table presents a complete set of summary statistics for the mean wage rate. For other measures of wage rates (i.e., top decile, median), the table only presents the mean. The typical mean hourly wage in the sample is about \$18. There is a substantial range in the wage distribution, as the wage at the first decile is about \$8 whereas the average at the ninth decile is over \$30. There is also substantial variation in hourly wages across occupations. Low-skill service jobs, such as food preparation and ground

maintenance are paid the least, at about \$10. High-skill occupations, such as legal work and engineering receive larger hourly salaries, at about \$30 and workers employed in management are paid the most, earning nearly \$40. Construction and extraction occupations, which are likely to be the most directly affected by the boom, receive average hourly wages of about \$20 per hour.

EMPIRICAL ANALYSIS

I examine the effects of the recent U.S. energy boom using a difference-in-differences (DiD) framework that compares how boom areas changed relative to nonboom areas during the period after production levels started increasing. Within the DiD framework, areas that did not experience the boom effectively serve as a control group that is used to compute a counterfactual for what boom areas would have experienced over time were it not for the energy boom. The extent by which boom areas differ from the counterfactual indicated by the nonboom areas provides an estimate of the effect of the energy boom.

Because the time period for which data are available differs across variables, the years used in the analysis depend on the outcome being examined. For each outcome, I compare the change in boom areas over time relative to the first year in which the outcome variable is available and discuss the trends within the context of corresponding changes in production levels. In general, I expect “boom effects” to steadily increase over time because the boom had not yet peaked as of 2014 (see Figure 1).

Comparison of Means

I begin the analysis by presenting a graphical comparison of means between boom and nonboom areas for three sets of variables: major economic variables (population, income per capita, net earnings per capita, and employment), wage rate variables, and housing variables. For each outcome presented, I display means annually for boom and nonboom areas. I also display how the difference in means between the two groups has changed since the beginning of the sample. Means are plotted against the left-hand axis, which is log-scaled. The difference in means, as measured in log points, is plotted on the right-hand axis.²⁴ When present, a divergent trend in means during the latter part of the 2000s is evidence that the energy boom affected an outcome.

Figure 5 presents estimates for major economic variables. These outcomes have generally been considered in other studies of energy booms and thus do not constitute the primary contribution of the paper, but they are helpful for initially characterizing the effects of the boom.²⁵ For each outcome, the trend is nearly flat until 2005, at which point the boom areas begin to increase relative to nonboom areas. The beginning of the apparent boom effects in 2005 is consistent with the change in production levels, which most clearly begin to diverge in 2006 (see Figure 3). The reason for the one-year delay in production is that wells take time to be completed, so while production changes began in 2006, operations related to drilling and

²⁴ The range of the right-hand axis is fixed across all graphs to facilitate comparisons across outcomes.

²⁵ Allcott and Keniston (2014); Fetzer (2014); Feyrer, Mansur, and Sacerdote (2015); and Maniloff and Mastromonaco (2014) each have recent working papers on the local effects of fracking, especially employment. Feyrer, Mansur, and Sacerdote find that fracking has led to 725,000 additional jobs and Fetzer indicates fracking is associated within 500,000–600,000 additional jobs. In contrast, and Maniloff and Mastromonaco indicate about 220,000 additional jobs. Allcott and Keniston, whose study spans multiple energy booms, find that employment increases by 2.9 percent during an energy boom in a county with a one standard deviation larger oil and gas endowment.

construction of related infrastructure likely began in the prior year.²⁶ Relative to nonboom areas, mean levels of population, income per capita, net earnings per capita, and employment all increased between 2001 and 2013.

Means related to overall hourly wage rates and employment are presented in Figure 6. Separate graphs are presented for the mean hourly wage and the hourly wage at the first decile, median, and ninth decile of the wage distribution. The year 2006 is the first year in the OES data and serves as the point of comparison in the graphs. Because the boom appears to have begun in 2005 (based on Figure 5), evaluating it by comparing changes relative to 2006 likely will lead to conservative estimates of the effect of the boom. Despite the conservative comparison, all hourly wage plots indicate that the boom has increased wage rates. The estimated effect is larger at the first decile and median than it is at the ninth decile.

Figure 7 presents a comparison of means for the housing variables. Similar to the major economic variables, the two groups appear to be on comparable trends during the early to mid-2000s. Starting in the latter 2000s, clear boom effects are present. Both owner-occupied housing values and rental prices have experienced relative increases in boom areas. The percentage increase in owner-occupied housing values is substantially larger than the increase in rental prices. The likely explanation for the larger effect on owner-occupied housing is that the increase reflects an increase in both demand for housing and value from royalty payments. There is no evidence that rent as a percentage of income increases, which indicates that renters are able to tap into the monetary benefits of the boom. There is little evidence that the boom has led to substantial amounts of new construction, as trends in housing units do not appear to diverge. The

²⁶ There are a variety of stages to predrilling and drilling. Initial geological surveys and permitting can take more than half a year; staking out the well and well pad boundaries takes one to two months; drilling and completion take about a month (Shale Reporter 2015).

lack of new construction suggests that effects of the boom can be attributed to actual price changes as opposed to a change in the composition of the housing stock.

Estimates

I next investigate the effects of the energy boom using a set of regressions. The primary purpose for the first set of estimates is to formalize the results that can be seen visually in the figures presenting the comparison of means. I then present a new set of results examining how the boom has affected wage rates across different occupational categories.

Estimates are based on a regression of the form

$$\text{Outcome}_{it} = \alpha_i + \gamma_t + \lambda_t \text{Boom}_i \times \text{Time Period}_t + \epsilon_{it}, \quad (1)$$

where i indexes areas, t indexes years, α_i is a vector of NMA fixed effects that controls for time-invariant differences across areas, γ_t is a set of year dummy variables that controls spatially uniform time trends, λ_t represents a set of coefficients on the interaction terms comprised of an indicator for whether an area is a boom area and a dummy variable corresponding to a year, and ϵ_{it} is an error term. In all estimates, standard errors are clustered by NMA. The coefficients of primary interest are those represented by λ_t , which indicate how boom areas changed relative to nonboom areas over the sample period. An increasing trend across years during the boom period (2005 and later) in the magnitudes of the coefficients on the interaction terms can be interpreted as evidence of boom effects.

Identification of the effects of the boom in the above specification depends exclusively on the assumption that nonboom areas provide a valid counterfactual for the time trend that would have been experienced in boom areas absent the boom (i.e. the “common trends” assumption). While not empirically testable, the validity of this assumption is supported by Figure 5, which indicates that boom and nonboom areas were on similar time trends in major

economic variables during the early 2000s, and Figure 7, which shows that there was not a substantial relative change in the difference in home values and number of housing units in boom and nonboom areas between 2000 and 2007. I investigate the sensitivity of the results to the choice of different control groups and in the following section.

Estimates that correspond to the comparison of means presented in Figures 5, 6, and 7 are reported in Tables 3, 4, and 5, respectively. The results reflect the patterns presented in the figures and can be summarized as follows.²⁷ Boom areas experienced relative increases in population (5.7 percent), income per capita (11.8 percent), earnings per capita (16.7 percent), and employment (13.6 percent) between 2001 and 2013. Mean wage rates increased by about 7 percent between 2006 and 2013. There is evidence that the wage effects were larger in the bottom part of the wage rate distribution as the increases for the first decile and first quartile of the wage rate distribution (7.1 percent and 9.7 percent) are larger than the increases for third quartile and ninth decile (6.2 percent and 4.8 percent). Both housing values and rental prices increased between 2007 and 2012, though the estimated increase in home values (12.5 percent) is more than double the effect on rent (5.0 percent).²⁸ All the changes are statistically significant.²⁹ Additionally, the insignificant coefficients on the interaction terms corresponding

²⁷ The estimates are not precisely identical to the effects indicated by the comparison of means because the comparison of means involves aggregating the data and then taking logs, whereas the estimates are calculated using logged variables and the disaggregated data. Relative to the estimates, the comparisons of means calculations implicitly place a greater weight on observations with larger values for the dependent variable.

²⁸ I choose 2007 as the year of reference for the housing variables because it is the first year of data that is available across all four variables.

Table 5 provides some modest evidence that the number of housing units increased in boom areas in 2012. This is unlikely to mean that the observed changes in home values and rental prices are driven by compositional changes because the effects on home values and rental prices emerge well before the effect on housing units. Also, alternative specifications discussed in the section titled “Robustness Checks” indicate a positive boom effect on housing values and rental prices, yet fail to show an increase in the number of housing units (e.g., Table C.3).

²⁹ Inferring significance for the housing variables (from the ACS) is complicated because the data, roughly, represent a rolling five-year average based on overlapping datasets. However, if the data are restricted to the 2009 and 2014 five-year estimates, which do not overlap, a DiD analysis produces point estimates that are nearly identical

to the early 2000s in Table 5 and the insignificant coefficient on interaction term corresponding to 2000 in Table 7 support the assumption that nonboom areas provide a valid counterfactual for time trends in boom areas.

I next examine how wage and employment effects varied across occupational categories. There are two reasons why variation across occupational categories is of interest. First, examining the extent to which wage effects spilled over outside of jobs directly related to extraction provides an indication of how much the benefits of the boom extended across the community. Second, examining how the wage effects relate to the employment effects sheds light on whether the changes in wage rates were driven by compositional changes (i.e., changes in the specific types of occupations comprising each major occupational category) or a more competitive overall labor market. An increase in wage rates in occupations that did not experience changes in employment would be most consistent with a more competitive overall labor market.

To investigate the labor market effects of the energy boom across occupations, I estimate models that are analogous to those that evaluate overall mean wage and employment effects (see columns [1] and [7] of Table 4), except that the outcomes in the new set of results are the mean wage rate and employment level for a specific occupational category. In order to present a consolidated set of results, the only coefficients I present from these models are the coefficients on the “Boom \times 2014” interaction term, which indicates the relative change in the outcome for boom areas since the beginning of the sample.

to those on the Boom \times 2012 term in Table 5, and the coefficients are significant for the specifications investigating home values and median rent.

The results, which are based on 44 separate regressions, are presented in Figure 8. The occupations are sorted based on the estimated wage effect. The coefficient for mean wage is significant at the 5 percent level in 18 of 22 cases, indicating that the boom has raised wage rates for almost every occupational category. The increase in wage rates is comparable across most categories, and the confidence interval for the wage estimates only fails to include the estimated effect across all occupations (7 percent) in two instances.

Changes in employment were much more varied across occupations than the changes in wage rates. Unsurprisingly, construction and extraction experienced the largest change, increasing by over 60 percent. Other occupations with significant changes include transportation and moving; life, physical, and social sciences (i.e., technicians); sales; architecture and engineering; personal care and service; office and administrative support; food preparation and serving; business and financial operations; legal; installation maintenance and repair; and computer and mathematical. Some of these occupations have likely increased because they are directly connected to the extraction sector (i.e., architecture and engineering), while others have likely increased due to the increase in population and daily visitors (i.e., food preparation and serving).

Strikingly, there is no evidence of a relationship between the wage effects and the employment effects. The correlations between the wage coefficient and employment coefficient across occupations is 0.07. Collectively, the wage and employment results are consistent with an overall increase in the competitiveness of the local labor market that required employers to pay more to hire and retain employees across occupations. The most likely explanation for the increase in the competitiveness of the local market is that migration was not sufficient to offset the increase in the demand for labor due to the costs of relocating and beliefs about the

temporary nature of energy booms. This interpretation is consistent with the results in Table 3, which indicate that the percentage increase in population caused by the boom was less than half the percentage increase in employment. Regardless of the cause, the increase in wages represents a substantial and perhaps surprisingly widespread benefit that accrued to local workers.

Robustness Checks

The validity of the difference-in-differences methodology hinges on the assumption that nonboom areas can be used to control for time trends that are unrelated to the boom. One way in which this assumption may be violated is if the boom contemporaneously affects some-production areas. Areas with some production tend to be located close to boom areas and are likely to have a subset of workers with skill sets that are particularly well-suited to economies with elevated levels of oil and gas production. Accordingly, these areas may be affected by the boom, most likely through out-migration. If some-production areas are affected by the boom, then using them as “control” areas could lead to bias.³⁰

To examine whether the results are robust to excluding some-production areas from the control group, I reestimate all the previous models after excluding these areas from the sample. The results from these models are presented in Tables A.1–A.3 and Figure A.1. The estimates are generally very similar to those presented in the earlier models. The wage rate point estimates are, if anything, slightly larger.

In a related set of estimates, I show that the key results are robust to dropping any NMA that is adjacent to a boom region. Dropping boom-adjacent NMAs is another way of addressing concerns that out-migration from control areas into boom areas biases the estimates because out-

³⁰ More formally, if some-production areas are also affected by the boom it would be a violation of the “stable unit treatment value assumption.”

migration should be most substantial in areas that are closest to booming areas. The results are presented in Tables A.4–A.6 and Figure A.2. The estimates in these tables are similar to those presented in the main text, which stands in contrast to what would be expected if out-migration from nearby areas was driving the results.

Finally, I show that the results are robust to changing the threshold used to define boom areas. In particular, I present results in Tables A.7–A.9 and Figure A.3 based on a boom threshold of \$100 million instead of \$500 million. Under the new definition there are 24 boom areas, as opposed to the original seventeen. Results are similar, though at times a bit smaller, as one might expect when the boom definition is adjusted to include areas going through more modest booms.

It should be noted that the analysis provides estimates of the average effect of the energy boom in boom areas. There may be anecdotal cases when wage rates remained unchanged or when housing and rental prices experienced larger changes. In general, if an area is at the epicenter of a boom, it is likely that the effects of a boom will be larger than if an area is going through a smaller boom or is on the fringe of a boom region.

CONCLUSION

The paper presents new evidence on the local effects of energy booms, an issue that has received considerable attention due to ongoing debates about drilling policies in the United States. In particular, I show that the recent U.S. energy boom has had a substantial positive effect on wage rates, housing values, and rental prices in local economies. Consistent with the boom creating a more competitive overall local labor market that benefited workers, the increase in wage rates occurred across almost all major occupational categories. Additionally, wage rates

increased in every segment of the wage rate distribution and the largest percentage effects were in the lower parts of the wage rate distribution. With respect to housing, the estimated increase in housing values (12.4 percent) was much larger than the increase in rental prices over the same period (5.0 percent).

The primary implication of this paper is that bans on drilling for oil and gas have negative monetary consequences for a wide variety of local residents. If energy development is prohibited, workers will not benefit from more competitive wage rates and homeowners will miss out on royalty payments and elevated housing values. While allowing drilling may lead to local price inflation, the evidence in this paper suggests that the labor market effects of the boom are sufficient to offset the increase in prices even for households, such as renters, who are most directly exposed to the price effects.³¹ These findings may be of interest to local jurisdictions, who at times have imposed their own regulations on drilling, and also to state or national policymakers evaluating larger-scale options. From a state or national perspective, the negative effects of bans on local economies are perhaps exacerbated by the fact that bans will have larger effects per person in rural communities with low population densities than in urban settings (due to the natural link between the amount of land and the size of oil and gas reserves). Rural communities have often been prioritized for policies encouraging economic development.³²

While the broad monetary benefits of the boom increase the importance of avoiding unnecessary restrictions on drilling, the findings should not be taken as a blanket endorsement for oil and gas extraction. Restrictions may be justified by nonmonetary concerns, such as

³¹ Renters are more exposed than home owners because increases in property values are costly for renters but beneficial for homeowners.

³² In principle, concerns about the distributional effects of a ban could be offset by a redistribution of revenue from other sources. In such a case, the estimates provided in this paper and elsewhere in the literature could be helpful in deriving the parameters of such a policy.

environmental degradation. Additionally, if drilling is allowed, it may still be optimal for local areas to collect impact fees (or at least receive revenue from state-level fees) in order to offset some of the negative effects of drilling such as increased depreciation of infrastructure. Some of this revenue might also be reserved to aid local economies in the inevitable transition into a post-boom economy.

Appropriately formulating policies on energy exploration and extraction at the local level and beyond requires a detailed understanding of the effects of energy production, especially with respect to the development of shale resources which have only recently become a significant component of U.S. energy production and are poised to remain so. While monetary and environmental factors are perhaps the most prominent outcomes that need to be considered, the effect of booms on other factors, such as road depreciation, highway safety, education and other public services, and energy security may also be important. Future research in these areas followed by the careful design of policies would be of substantial local and national benefit.

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Figures and Tables

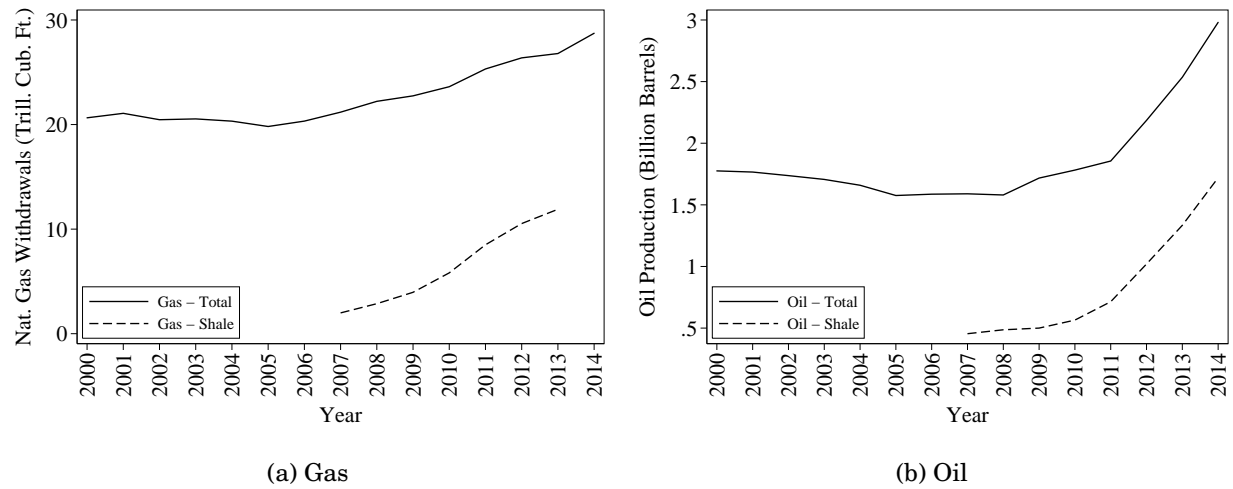


Figure 1: **National Trends in Oil and Gas Production in Continental U.S.** The data sources are the USEIA (2015a) and USEIA (2015b).

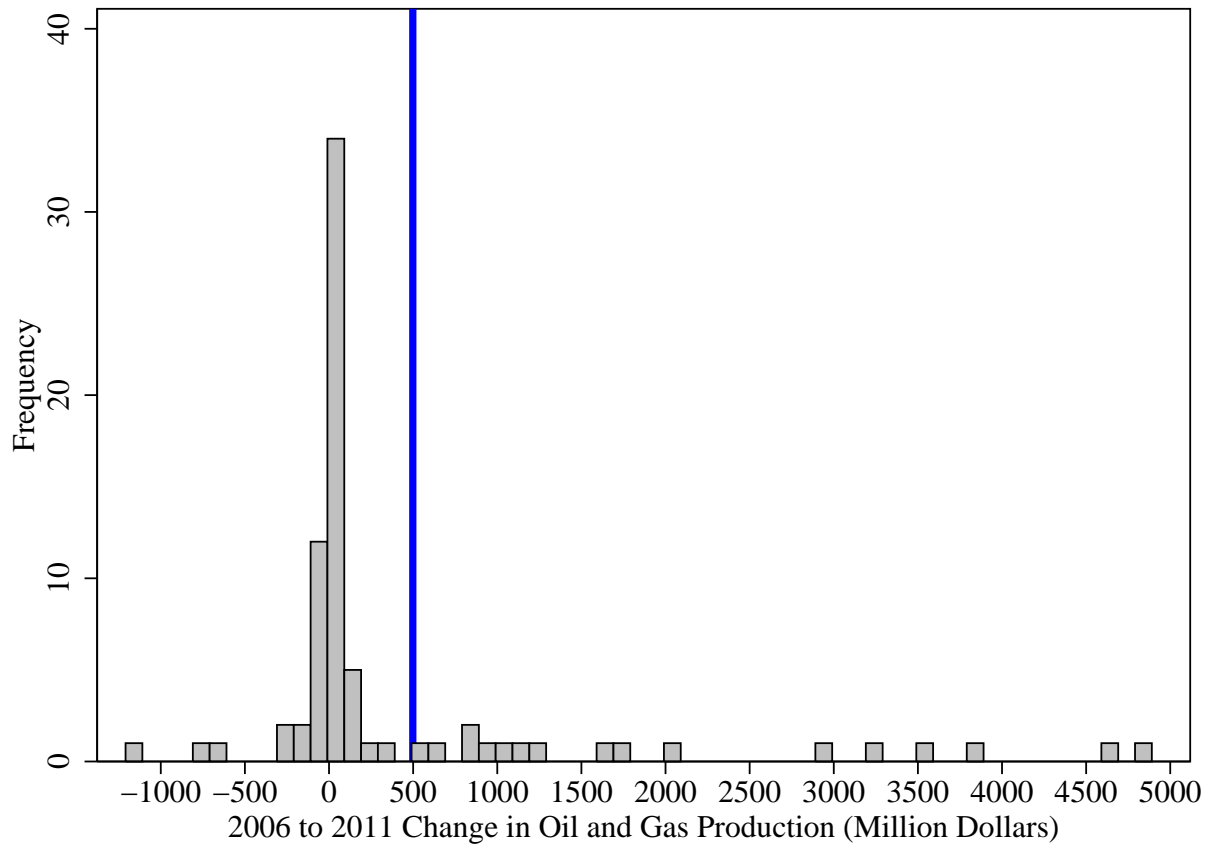


Figure 2: **Histogram of Change in Annual Oil and Gas Production from 2006 to 2011.** Areas with zero production are excluded from the data used for the histogram. The vertical line corresponds to the \$500 million threshold used for the definition of a “boom” area.

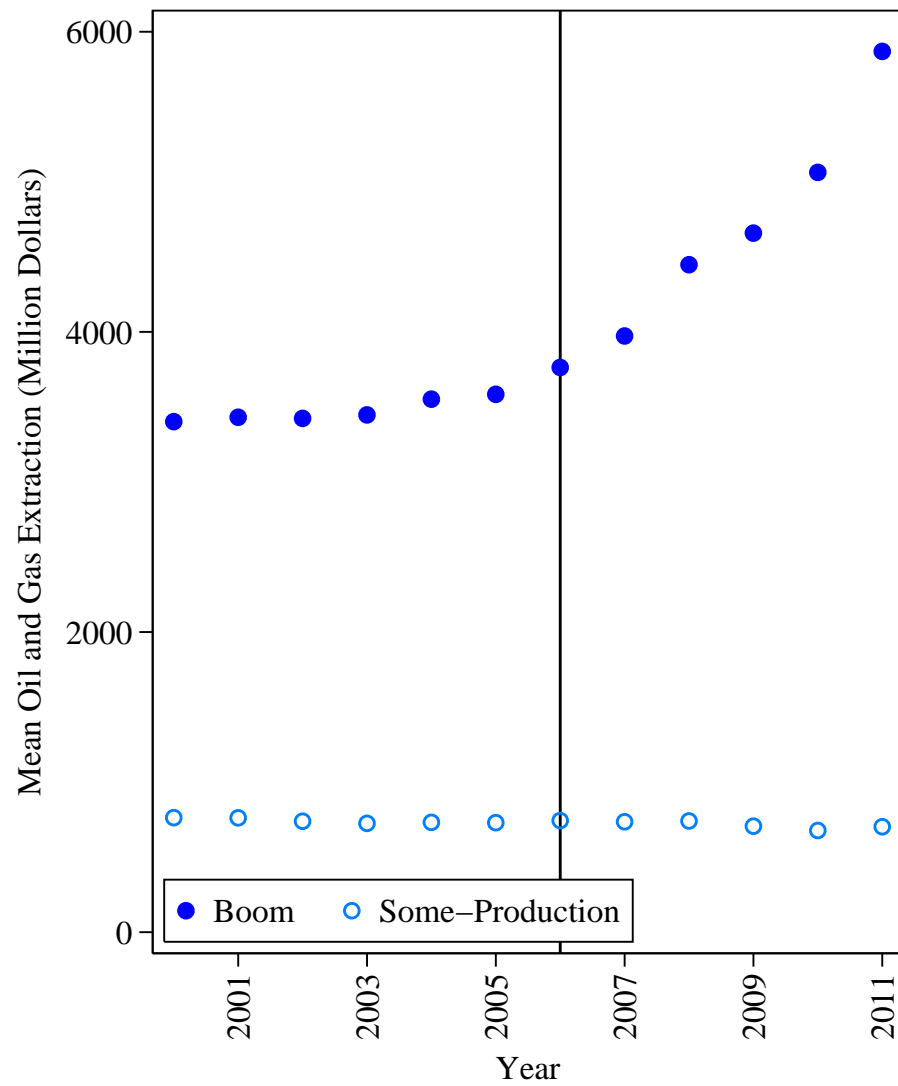


Figure 3: **Trends in Mean Oil and Gas Revenue by Category.**
There are 17 boom areas and 60 some-production areas.

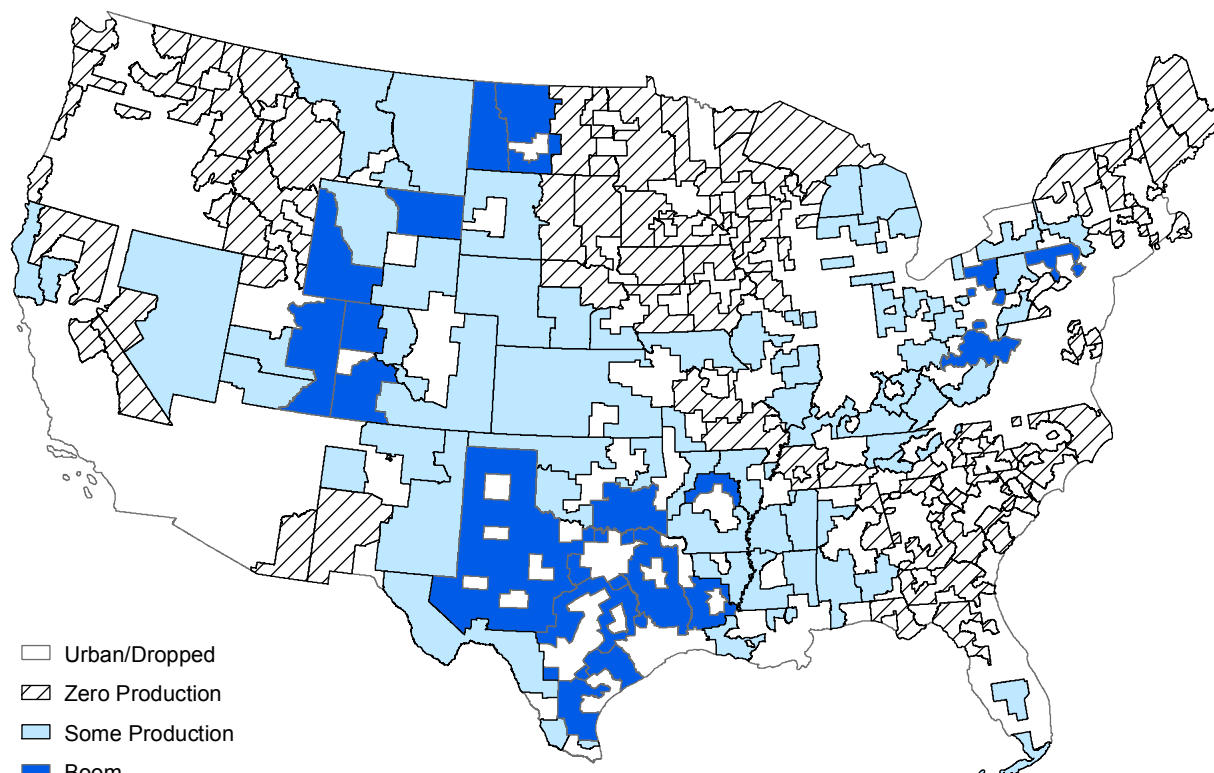


Figure 4: **Map of Boom Areas.** Non-white polygons represent non-metropolitan areas (NMAs) as defined by the Bureau of Labor Statistics.

Table 1: Summary Statistics for Non-Wage Variables

Variable	Mean	St. Dev.	Min.	Max.	Obs.
Boom	0.11	0.31	0.0	1.0	2,295
Some Production	0.39	0.49	0.0	1.0	2,295
Zero Production	0.50	0.50	0.0	1.0	2,295
Oil (Thous. Brrls.)	4,605.63	21,986.17	0.0	294,551.8	1,836
Gas (MMcf)	80,994.30	228,443.11	0.0	1,833,681.5	1,836
Oil and Gas Production (Mlln. \$s)	736.43	2,379.13	0.0	27,689.9	1,836
Chg. in Oil and Gas Prod. (Mlln. \$s)	217.94	826.92	-1,159.4	4,868.3	2,295
Population	311,742.25	204,955.06	17,610.0	1,000,724.0	1,989
Income per Capita	35,427.06	7,317.42	20,827.1	90,724.9	1,989
Net Earnings per Capita	21,185.84	5,677.48	11,963.4	70,124.4	1,989
Median Owner-Occupied Home Value	146,791.44	74,953.23	55,965.3	510,415.0	1,071
Median Gross Rent	701.98	151.82	460.3	1,326.9	918
Median Rent as Percentage of Income	28.74	2.97	19.2	37.3	918
Housing Units	149,253.44	94,641.22	7,937.0	532,382.0	1,071

Notes: The unit of observation is an NMA and a year. Data sources are the USDA (2014), the USBEA (2015), and the US Census (2015).

Table 2: Summary Statistics for Wage Rate and Employment by Occupation

Variable Summary Statistic	Mean Wage Rate					Measure of Wage Rate					Emp. Mean
	Mean	St. Dev.	Min.	Max.	Obs.	1st Dec. Mean	1st Qrt. Mean	Median Mean	3rd Qrt. Mean	9th Dec. Mean	
All Occupations	18.12	2.49	14.6	41.0	1,373	8.45	10.32	14.77	21.99	31.47	105,134.63
Architecture And Engineering	31.24	3.79	21.5	55.7	1,352	16.72	21.80	29.36	38.65	48.56	1,261.52
Arts, Design, Ent., Sports, And Media	17.90	3.02	10.5	39.0	1,353	8.78	10.83	15.23	22.08	30.56	844.13
Building And Grounds Cleaning And Maint.	11.69	1.44	8.9	19.7	1,376	8.06	8.96	10.67	13.45	16.98	3,611.73
Business And Financial Operations	27.27	2.98	20.6	50.3	1,356	14.43	18.81	24.98	33.07	42.61	2,703.87
Community And Social Service	19.38	2.26	14.3	28.4	1,356	10.77	13.81	18.30	23.92	29.92	1,669.76
Computer And Mathematical	28.55	3.72	19.0	46.4	1,349	15.08	19.66	26.54	35.38	45.18	847.80
Construction And Extraction	19.27	2.93	13.7	33.3	1,373	11.40	14.10	17.94	23.07	29.28	5,457.51
Education, Training, And Library	21.09	2.77	15.0	36.7	1,363	9.89	13.50	20.53	26.97	32.86	7,897.22
Farming, Fishing, And Forestry	14.44	2.31	7.5	23.1	1,304	8.89	10.47	13.18	17.13	22.06	680.37
Food Preparation And Serving Related	9.85	1.05	7.9	15.7	1,377	7.69	8.12	8.98	10.65	13.50	9,595.76
Healthcare Practitioners And Technical	30.84	3.76	22.9	46.0	1,368	13.48	18.25	25.27	34.18	53.21	5,827.02
Healthcare Support	12.42	1.62	8.7	19.8	1,368	8.80	9.95	11.62	13.98	17.15	3,598.00
Installation, Maintenance, And Repair	19.76	2.06	15.1	32.9	1,364	10.73	13.88	18.47	24.38	31.11	4,970.16
Legal	32.05	6.85	14.7	58.4	1,299	13.78	17.94	25.60	39.60	57.25	405.71
Life, Physical, And Social Science	26.64	3.16	18.2	43.2	1,325	14.11	18.12	24.55	32.80	41.72	765.03
Management	39.41	4.76	26.9	67.5	1,360	17.19	24.90	35.14	47.90	65.51	4,025.29
Office And Administrative Support	14.68	1.40	12.2	23.8	1,376	8.79	10.64	13.58	17.47	22.30	15,563.55
Personal Care And Service	11.20	1.31	7.6	17.8	1,357	7.87	8.56	9.89	12.29	16.54	2,661.95
Production	16.38	2.27	12.0	28.7	1,355	9.40	11.49	15.00	19.71	25.48	11,469.59
Protective Service	18.85	3.63	12.7	32.5	1,349	9.99	13.26	18.10	23.24	28.88	2,740.48
Sales And Related	14.24	1.51	10.5	21.4	1,375	7.96	8.75	10.64	15.82	24.77	10,367.26
Transportation And Material Moving	15.35	1.78	11.7	24.2	1,368	8.60	10.54	14.05	18.52	24.13	8,386.73

Notes: The unit of observation is an NMA and a year. The data source is the USBLS (2015). With the exception of the final column, this table presents summary statistics for various measures of hourly wage rates. For example, the 1st row indicates that, across NMAs, the average mean hourly wage rate across all occupations is \$18.12, and the average hourly wage rate at the first decile, first quartile, median, third quartile, and ninth decile of the wage rate distribution across all occupations is \$8.45, \$10.32, \$14.77, \$21.99, and \$31.46, respectively. The final column presents mean employment levels. Each row presents results for the corresponding occupational category as indicated by the first column.

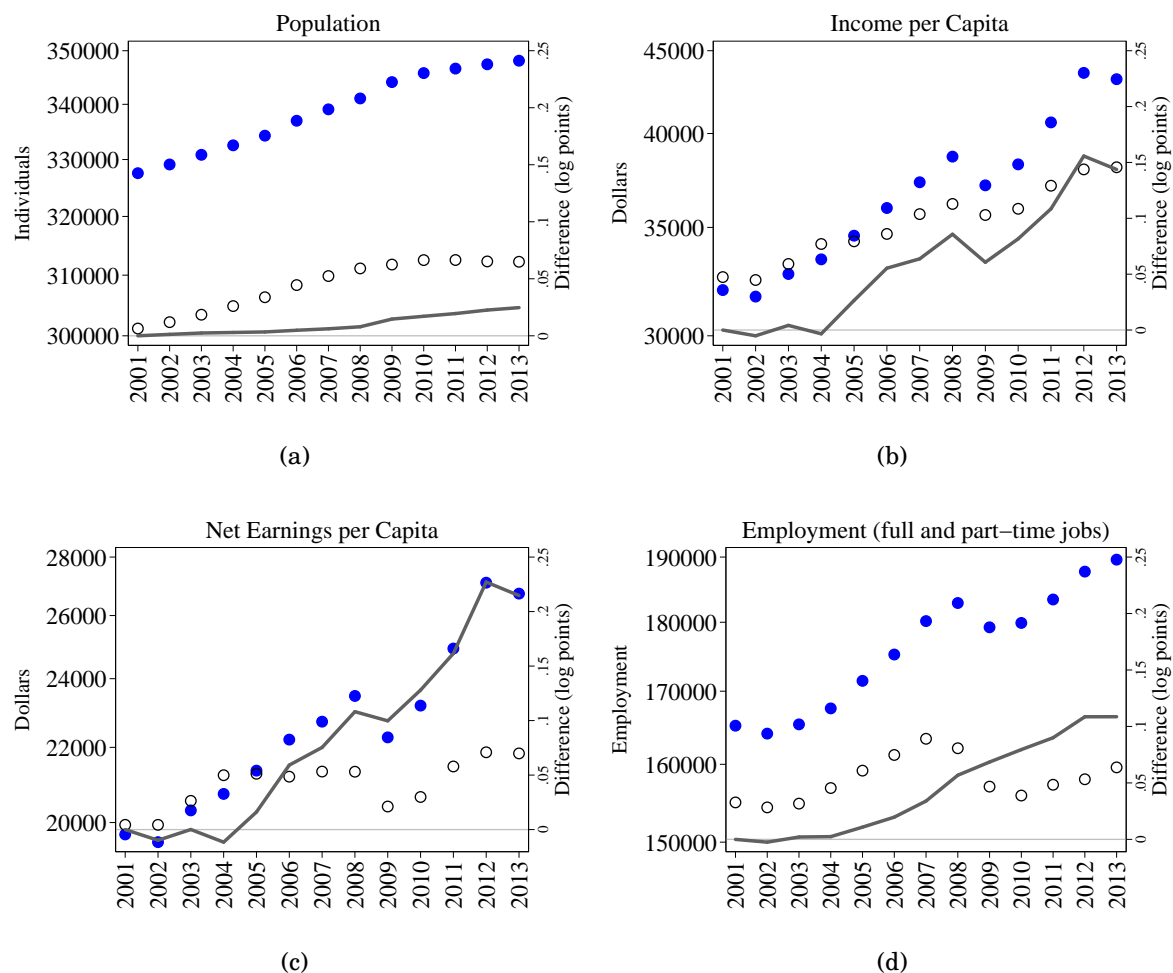
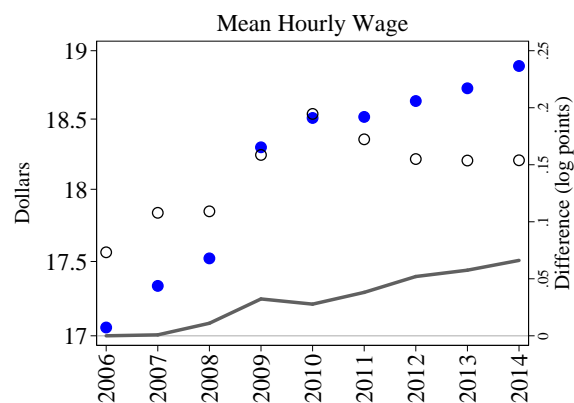
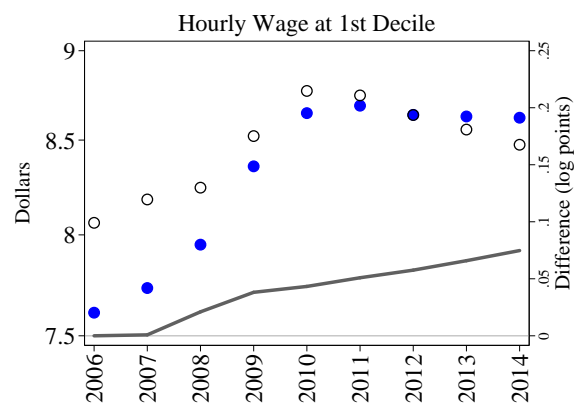


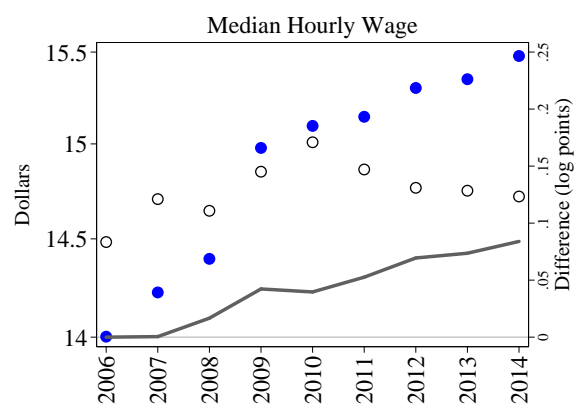
Figure 5: Comparison of Trends in Means for Major Economic Variables. In the scatter plots, solid markers represent boom areas and hollow markers represent non-boom areas and the markers are plotted on the left axis. The gray line represents the difference between the two groups relative to the difference in 2001 and is plotted on the right axis.



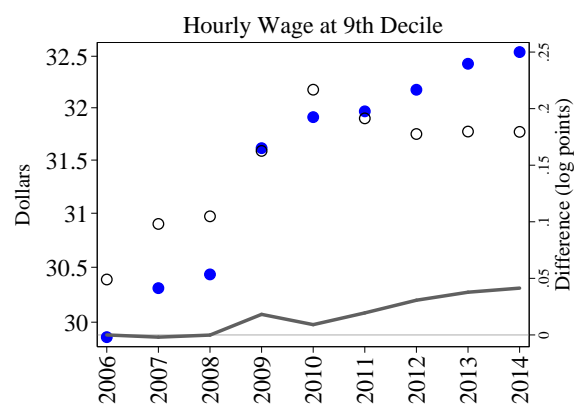
(a)



(b)



(c)



(d)

Figure 6: Comparison of Trends in Means for Wage Variables. In the scatter plots, solid markers represent boom areas and hollow markers represent non-boom areas and the markers are plotted on the left axis. The gray line represents the difference between the two groups relative to the difference in 2006 and is plotted on the right axis.

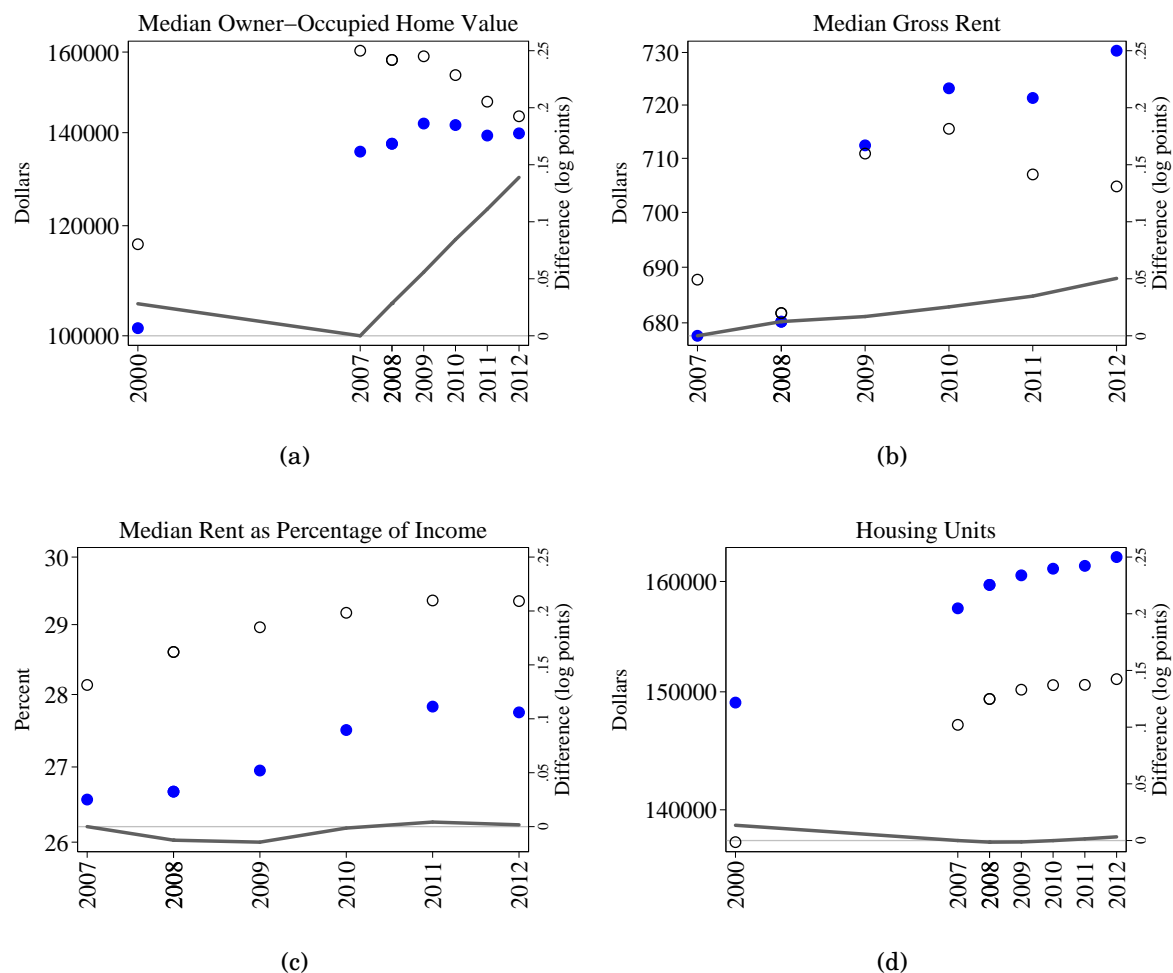


Figure 7: Comparison of Trends in Means for Housing Variables. In the scatter plots, solid markers represent boom areas and hollow markers represent non-boom areas and the markers are plotted on the left axis. The gray line represents the difference between the two groups relative to the difference in 2007 and is plotted on the right axis. Years correspond to the center years of the 5-year estimates reported by the ACS.

Table 3: Estimates of the Effect of the Boom on Major Economic Variables Relative to 2001

	ln(Pop.)	ln(Inc. Per Cap.)	ln(Earn. per Cap.)	ln(Emp.)
	(1)	(2)	(3)	(4)
Boom × 2002	0.003 (0.002)	-0.006 (0.005)	-0.011* (0.006)	-0.003 (0.003)
Boom × 2003	0.003 (0.004)	0.002 (0.008)	-0.002 (0.012)	-0.002 (0.004)
Boom × 2004	0.004 (0.005)	-0.006 (0.007)	-0.012 (0.008)	0.000 (0.006)
Boom × 2005	0.005 (0.007)	0.021* (0.012)	0.012 (0.014)	0.009 (0.009)
Boom × 2006	0.008 (0.009)	0.044** (0.019)	0.050*** (0.019)	0.023* (0.014)
Boom × 2007	0.014 (0.012)	0.053*** (0.018)	0.064*** (0.023)	0.039** (0.017)
Boom × 2008	0.019 (0.015)	0.077*** (0.021)	0.096*** (0.031)	0.065*** (0.020)
Boom × 2009	0.030* (0.017)	0.056*** (0.021)	0.088** (0.036)	0.076*** (0.018)
Boom × 2010	0.034** (0.017)	0.073*** (0.028)	0.113** (0.044)	0.089*** (0.019)
Boom × 2011	0.039** (0.017)	0.094** (0.038)	0.138** (0.057)	0.108*** (0.028)
Boom × 2012	0.049** (0.019)	0.128** (0.053)	0.177** (0.075)	0.135*** (0.039)
Boom × 2013	0.057** (0.022)	0.118** (0.050)	0.167** (0.073)	0.136*** (0.044)
<i>R</i> -squared	0.338	0.624	0.262	0.396
Obs.	1989	1989	1989	1989

Notes: Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

Table 4: Estimates of the Effect of the Boom on Wage Rates and Employment Relative to 2006

	Wage Measure					
	Mean (1)	1st Dec. (2)	1st Qrt. (3)	Median (4)	3rd Qrt. (5)	9th Dec. (6)
Boom \times 2007	0.009*** (0.003)	0.003 (0.006)	0.011*** (0.004)	0.010*** (0.003)	0.002 (0.003)	0.007** (0.004)
Boom \times 2008	0.019*** (0.005)	0.022*** (0.006)	0.027*** (0.006)	0.025*** (0.005)	0.008 (0.006)	0.009 (0.006)
Boom \times 2009	0.032*** (0.008)	0.037*** (0.006)	0.043*** (0.008)	0.042*** (0.007)	0.023** (0.009)	0.019** (0.009)
Boom \times 2010	0.036*** (0.009)	0.044*** (0.007)	0.054*** (0.008)	0.049*** (0.008)	0.028*** (0.010)	0.019* (0.010)
Boom \times 2011	0.046*** (0.013)	0.052*** (0.009)	0.066*** (0.013)	0.061*** (0.016)	0.036*** (0.014)	0.029** (0.012)
Boom \times 2012	0.059*** (0.016)	0.058*** (0.012)	0.077*** (0.019)	0.076*** (0.021)	0.050*** (0.017)	0.040*** (0.014)
Boom \times 2013	0.064*** (0.018)	0.065*** (0.016)	0.083*** (0.023)	0.080*** (0.023)	0.057*** (0.018)	0.047*** (0.016)
Boom \times 2014	0.070*** (0.021)	0.071*** (0.019)	0.097*** (0.026)	0.089*** (0.024)	0.062*** (0.020)	0.048** (0.019)
<i>R</i> -squared	0.429	0.610	0.235	0.235	0.305	0.360
Obs.	1373	1373	1373	1373	1373	1373

Notes: Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

Table 5: Estimates of the Effect of the Boom on Housing Relative to 2000 or 2007

	ln(Home Value) (1)	ln(Med. Rent) (2)	ln(Rent as % of Inc.) (3)	ln(Housing Units) (4)
Boom × 2000	0.017 (0.031)			0.007 (0.011)
Boom × 2008	0.023*** (0.004)	0.013*** (0.004)	-0.010* (0.006)	0.008 (0.008)
Boom × 2009	0.045*** (0.010)	0.017** (0.007)	-0.012 (0.009)	0.010 (0.010)
Boom × 2010	0.073*** (0.018)	0.026** (0.010)	0.002 (0.014)	0.014 (0.011)
Boom × 2011	0.099*** (0.028)	0.034** (0.016)	0.008 (0.015)	0.019 (0.012)
Boom × 2012	0.124*** (0.036)	0.050** (0.021)	0.004 (0.016)	0.025* (0.014)
<i>R</i> -squared	0.677	0.553	0.302	0.621
Obs.	1071	918	918	1071

Notes: Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Years correspond to the center years of the 5-year estimates reported by the ACS. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

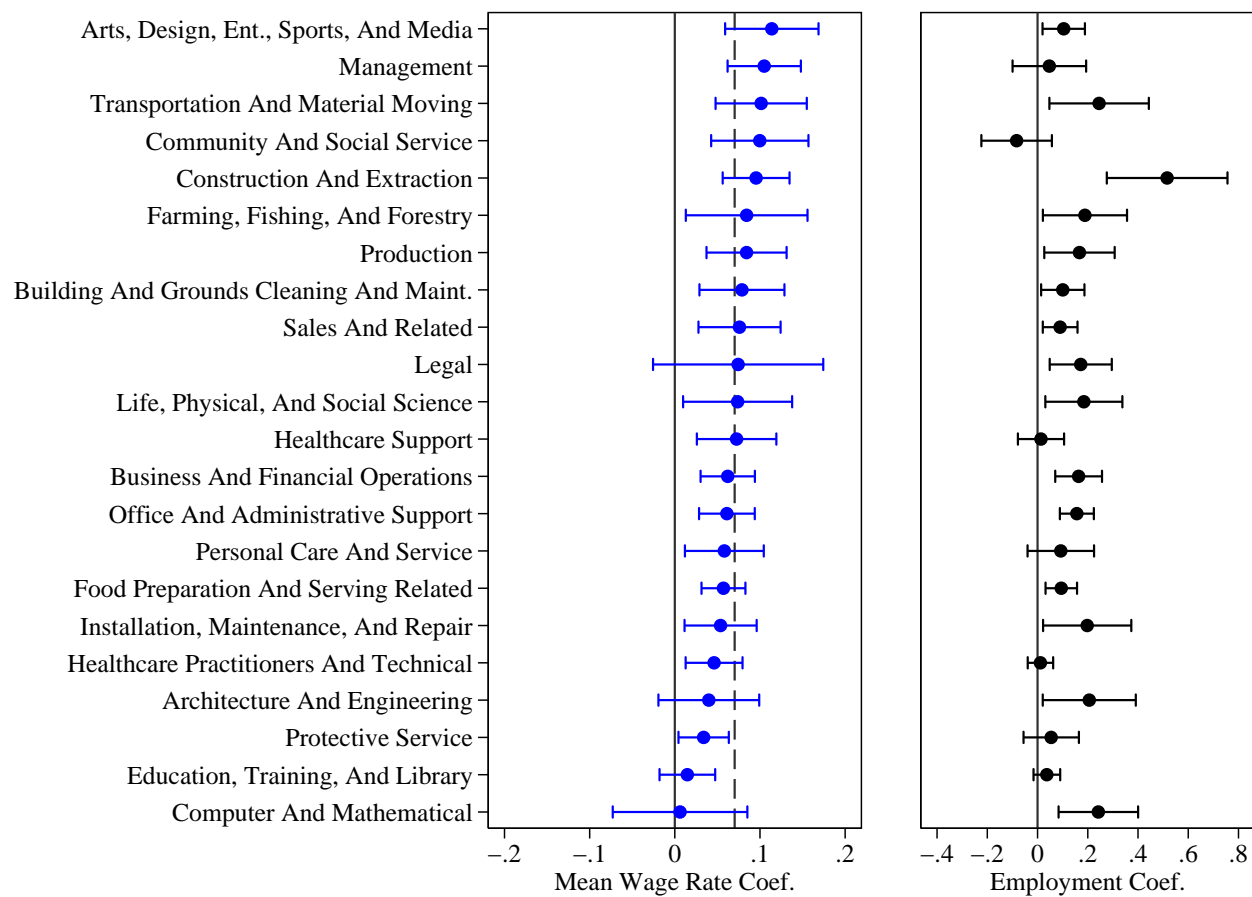


Figure 8: Estimates of the Effect of the Boom on Wage Rates and Employment in 2014 Relative to 2006 for Each Occupational Category. Each coefficient comes from a separate regression with the corresponding dependent variable as indicated by both axes. The coefficients presented are those on the “Boom \times 2014” interaction terms. The vertical dashed line represents the overall estimate across all occupations (see the first column of Table 4). The whiskers represent 95-percent confidence intervals. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level.

A Appendix - FOR ONLINE PUBLICATION ONLY

A.1 Robustness Checks: Dropping Some-Production NMAs

Table A.1: Estimates of the Effect of the Boom on Major Economic Variables Relative to 2001; Dropping Some-Production NMAs

	ln(Pop.)	ln(Inc. Per Cap.)	ln(Earn. per Cap.)	ln(Emp.)
	(1)	(2)	(3)	(4)
Boom × 2002	0.001 (0.003)	-0.008 (0.005)	-0.014** (0.007)	-0.005 (0.003)
Boom × 2003	-0.001 (0.004)	0.002 (0.008)	-0.004 (0.013)	-0.006 (0.005)
Boom × 2004	-0.002 (0.006)	-0.008 (0.008)	-0.014 (0.009)	-0.008 (0.007)
Boom × 2005	-0.002 (0.008)	0.022* (0.012)	0.012 (0.014)	-0.002 (0.010)
Boom × 2006	0.001 (0.010)	0.045** (0.019)	0.051*** (0.019)	0.012 (0.014)
Boom × 2007	0.005 (0.013)	0.054*** (0.019)	0.064*** (0.024)	0.029 (0.018)
Boom × 2008	0.009 (0.015)	0.081*** (0.022)	0.100*** (0.032)	0.058*** (0.021)
Boom × 2009	0.021 (0.017)	0.060*** (0.022)	0.091** (0.037)	0.070*** (0.018)
Boom × 2010	0.024 (0.017)	0.080*** (0.029)	0.120*** (0.045)	0.086*** (0.020)
Boom × 2011	0.030* (0.018)	0.103** (0.039)	0.149** (0.058)	0.107*** (0.028)
Boom × 2012	0.040** (0.020)	0.136** (0.054)	0.188** (0.077)	0.135*** (0.040)
Boom × 2013	0.048** (0.023)	0.129** (0.051)	0.183** (0.074)	0.135*** (0.044)
<i>R</i> -squared	0.410	0.583	0.268	0.458
Obs.	1209	1209	1209	1209

Notes: Observations for some-production NMAs were excluded from the model. Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

Table A.2: Estimates of the Effect of the Boom on Wage Rates and Employment Relative to 2006; Dropping Some-Production NMAs

	Wage Measure					
	Mean (1)	1st Dec. (2)	1st Qrt. (3)	Median (4)	3rd Qrt. (5)	9th Dec. (6)
Boom × 2007	0.012*** (0.003)	0.007 (0.007)	0.014*** (0.004)	0.012*** (0.003)	0.006 (0.004)	0.009** (0.004)
Boom × 2008	0.022*** (0.006)	0.032*** (0.007)	0.032*** (0.007)	0.029*** (0.005)	0.012* (0.007)	0.010 (0.007)
Boom × 2009	0.035*** (0.008)	0.052*** (0.007)	0.049*** (0.009)	0.045*** (0.008)	0.027*** (0.010)	0.019* (0.010)
Boom × 2010	0.040*** (0.009)	0.064*** (0.008)	0.063*** (0.009)	0.053*** (0.009)	0.032*** (0.010)	0.018 (0.011)
Boom × 2011	0.051*** (0.013)	0.075*** (0.011)	0.076*** (0.013)	0.066*** (0.016)	0.041*** (0.014)	0.029** (0.013)
Boom × 2012	0.066*** (0.017)	0.082*** (0.013)	0.089*** (0.019)	0.084*** (0.021)	0.057*** (0.017)	0.042*** (0.015)
Boom × 2013	0.070*** (0.018)	0.089*** (0.017)	0.095*** (0.023)	0.088*** (0.023)	0.063*** (0.018)	0.049*** (0.017)
Boom × 2014	0.078*** (0.021)	0.095*** (0.019)	0.107*** (0.027)	0.097*** (0.025)	0.069*** (0.020)	0.052** (0.020)
<i>R</i> -squared	0.438	0.554	0.272	0.274	0.311	0.368
Obs.	834	834	834	834	834	834

Notes: Observations for some-production NMAs were excluded from the model. Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

Table A.3: Estimates of the Effect of the Boom on Housing Relative to 2007; Dropping Some-Production NMAs

	ln(Home Value) (1)	ln(Med. Rent) (2)	ln(Rent as % of Inc.) (3)	ln(Housing Units) (4)
Boom × 2000	0.067* (0.034)			0.017 (0.011)
Boom × 2008	0.024*** (0.005)	0.013*** (0.004)	-0.012* (0.006)	0.001 (0.008)
Boom × 2009	0.050*** (0.010)	0.017** (0.007)	-0.018* (0.010)	0.002 (0.010)
Boom × 2010	0.084*** (0.019)	0.025** (0.011)	-0.004 (0.014)	0.005 (0.011)
Boom × 2011	0.116*** (0.029)	0.034** (0.016)	0.002 (0.015)	0.010 (0.013)
Boom × 2012	0.146*** (0.037)	0.051** (0.021)	-0.001 (0.016)	0.015 (0.014)
<i>R</i> -squared	0.748	0.555	0.361	0.699
Obs.	651	558	558	651

Notes: Observations for some-production NMAs were excluded from the model. Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Years correspond to the center years of the 5-year estimates reported by the ACS. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

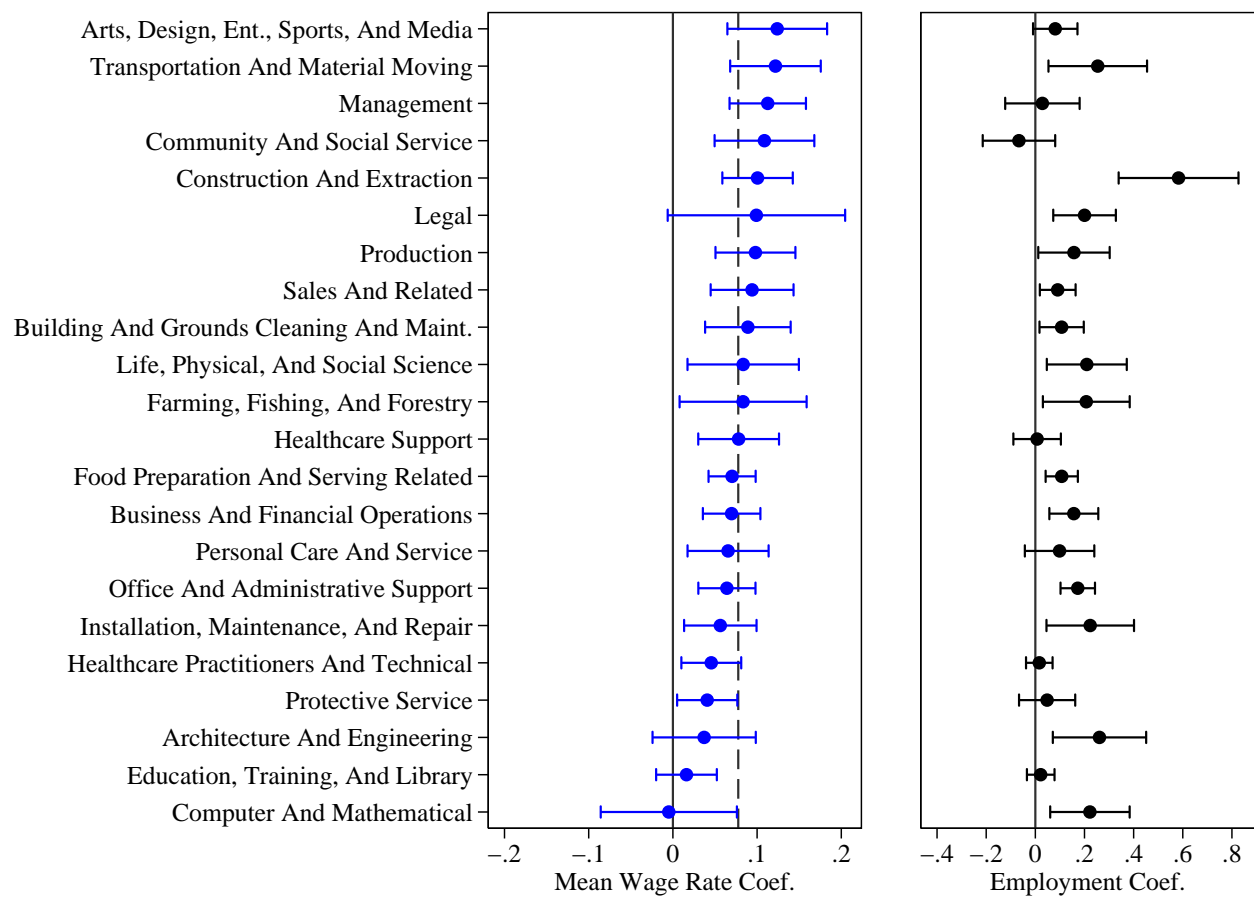


Figure A.1: Estimates of the Effect of the Boom on Wage Rates and Employment in 2014 Relative to 2006 for Each Occupational Category; Dropping Some-Production NMAs. Observations for some-production NMAs were excluded from the model. Each coefficient comes from a separate regression with the corresponding dependent variable as indicated by both axes. The coefficients presented are those on the “Boom \times 2014” interaction terms. The vertical dashed line represents the overall estimate across all occupations (see the first column of Table A.2). The whiskers represent 95-percent confidence intervals. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level.

A.2 Robustness Checks: Dropping Boom-Adjacent NMAs

Table A.4: Estimates of the Effect of the Boom on Major Economic Variables Relative to 2001; Dropping Boom-Adjacent NMAs

	ln(Pop.)	ln(Inc. Per Cap.)	ln(Earn. per Cap.)	ln(Emp.)
	(1)	(2)	(3)	(4)
Boom × 2002	0.002 (0.003)	-0.007 (0.005)	-0.014** (0.006)	-0.003 (0.003)
Boom × 2003	0.001 (0.004)	0.004 (0.008)	-0.001 (0.012)	-0.003 (0.004)
Boom × 2004	0.001 (0.005)	-0.007 (0.007)	-0.014 (0.009)	-0.002 (0.007)
Boom × 2005	0.002 (0.007)	0.023* (0.012)	0.014 (0.014)	0.006 (0.010)
Boom × 2006	0.005 (0.010)	0.047** (0.019)	0.052*** (0.019)	0.021 (0.014)
Boom × 2007	0.010 (0.013)	0.059*** (0.018)	0.072*** (0.023)	0.039** (0.018)
Boom × 2008	0.016 (0.015)	0.088*** (0.021)	0.109*** (0.031)	0.070*** (0.020)
Boom × 2009	0.028 (0.017)	0.063*** (0.021)	0.096*** (0.037)	0.082*** (0.018)
Boom × 2010	0.032* (0.017)	0.082*** (0.028)	0.126*** (0.044)	0.097*** (0.019)
Boom × 2011	0.038** (0.017)	0.106*** (0.039)	0.153*** (0.057)	0.117*** (0.028)
Boom × 2012	0.048** (0.020)	0.143*** (0.053)	0.198** (0.076)	0.145*** (0.040)
Boom × 2013	0.056** (0.022)	0.130** (0.050)	0.184** (0.073)	0.145*** (0.044)
<i>R</i> -squared	0.367	0.609	0.277	0.431
Obs.	1521	1521	1521	1521

Notes: Observations for NMAs located adjacent to boom areas were excluded from the model. Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

Table A.5: Estimates of the Effect of the Boom on Wage Rates and Employment Relative to 2006; Dropping Boom-Adjacent NMAs

	Wage Measure					
	Mean (1)	1st Dec. (2)	1st Qrt. (3)	Median (4)	3rd Qrt. (5)	9th Dec. (6)
Boom × 2007	0.010*** (0.003)	0.008 (0.006)	0.013*** (0.004)	0.010*** (0.003)	0.004 (0.003)	0.007* (0.004)
Boom × 2008	0.021*** (0.005)	0.030*** (0.006)	0.031*** (0.007)	0.028*** (0.005)	0.011 (0.007)	0.010 (0.006)
Boom × 2009	0.036*** (0.008)	0.046*** (0.006)	0.049*** (0.009)	0.045*** (0.008)	0.026*** (0.010)	0.020** (0.009)
Boom × 2010	0.041*** (0.009)	0.056*** (0.007)	0.063*** (0.008)	0.055*** (0.008)	0.033*** (0.010)	0.021** (0.010)
Boom × 2011	0.053*** (0.013)	0.066*** (0.010)	0.076*** (0.013)	0.069*** (0.016)	0.043*** (0.014)	0.032*** (0.012)
Boom × 2012	0.068*** (0.016)	0.072*** (0.012)	0.088*** (0.019)	0.086*** (0.021)	0.059*** (0.017)	0.045*** (0.014)
Boom × 2013	0.072*** (0.018)	0.079*** (0.016)	0.094*** (0.023)	0.090*** (0.023)	0.064*** (0.018)	0.050*** (0.016)
Boom × 2014	0.078*** (0.021)	0.086*** (0.019)	0.107*** (0.026)	0.098*** (0.024)	0.069*** (0.020)	0.052*** (0.019)
<i>R</i> -squared	0.445	0.581	0.284	0.281	0.322	0.391
Obs.	1050	1050	1050	1050	1050	1050

Notes: Observations for NMAs located adjacent to boom areas were excluded from the model. Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

Table A.6: Estimates of the Effect of the Boom on Housing Relative to 2007; Dropping Boom-Adjacent NMAs

	ln(Home Value) (1)	ln(Med. Rent) (2)	ln(Rent as % of Inc.) (3)	ln(Housing Units) (4)
Boom \times 2000	0.038 (0.033)			0.011 (0.011)
Boom \times 2008	0.027*** (0.004)	0.011*** (0.004)	-0.011* (0.006)	0.006 (0.008)
Boom \times 2009	0.056*** (0.010)	0.015** (0.007)	-0.015 (0.009)	0.009 (0.010)
Boom \times 2010	0.089*** (0.019)	0.024** (0.010)	-0.001 (0.014)	0.013 (0.011)
Boom \times 2011	0.121*** (0.028)	0.034** (0.016)	0.005 (0.015)	0.018 (0.012)
Boom \times 2012	0.149*** (0.037)	0.052** (0.021)	0.003 (0.016)	0.023 (0.014)
<i>R</i> -squared	0.689	0.583	0.351	0.660
Obs.	819	702	702	819

Notes: Observations for NMAs located adjacent to boom areas were excluded from the model. Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Years correspond to the center years of the 5-year estimates reported by the ACS. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

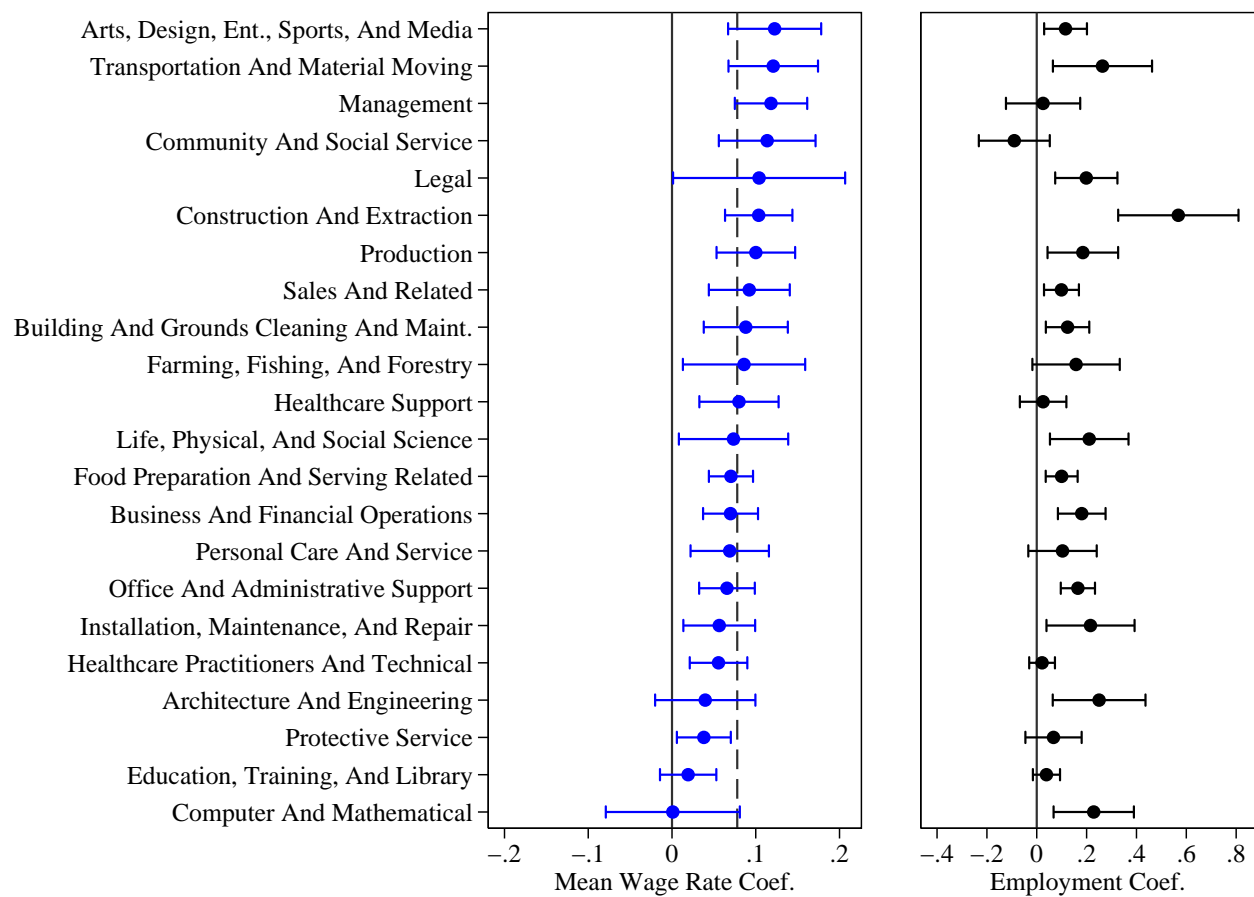


Figure A.2: Estimates of the Effect of the Boom on Wage Rates and Employment in 2014 Relative to 2006 for Each Occupational Category; Dropping Boom-Adjacent NMAs. Observations for NMAs located adjacent to boom areas were excluded from the model. Each coefficient comes from a separate regression with the corresponding dependent variable as indicated by both axes. The coefficients presented are those on the “Boom \times 2014” interaction terms. The vertical dashed line represents the overall estimate across all occupations (see the first column of Table A.5). The whiskers represent 95-percent confidence intervals. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level.

A.3 Robustness Checks: Boom Threshold of \$100 Million

Table A.7: Estimates of the Effect of the Boom on Major Economic Variables Relative to 2001; Boom Threshold of \$100 Million

	ln(Pop.)	ln(Inc. Per Cap.)	ln(Earn. per Cap.)	ln(Emp.)
	(1)	(2)	(3)	(4)
Boom × 2002	0.000 (0.002)	-0.006 (0.004)	-0.013** (0.005)	-0.005* (0.002)
Boom × 2003	-0.002 (0.003)	-0.003 (0.006)	-0.006 (0.010)	-0.006* (0.004)
Boom × 2004	-0.004 (0.005)	-0.009 (0.006)	-0.014* (0.007)	-0.010* (0.006)
Boom × 2005	-0.005 (0.006)	0.015* (0.009)	0.010 (0.011)	-0.006 (0.008)
Boom × 2006	-0.004 (0.008)	0.031** (0.015)	0.038** (0.015)	0.005 (0.012)
Boom × 2007	-0.002 (0.010)	0.035** (0.015)	0.046** (0.018)	0.016 (0.015)
Boom × 2008	0.000 (0.012)	0.057*** (0.017)	0.073*** (0.025)	0.038** (0.017)
Boom × 2009	0.008 (0.014)	0.044*** (0.017)	0.066** (0.028)	0.047*** (0.016)
Boom × 2010	0.009 (0.014)	0.060*** (0.021)	0.091*** (0.033)	0.059*** (0.018)
Boom × 2011	0.012 (0.015)	0.073** (0.029)	0.108** (0.043)	0.073*** (0.023)
Boom × 2012	0.018 (0.017)	0.098** (0.040)	0.141** (0.056)	0.092*** (0.032)
Boom × 2013	0.023 (0.019)	0.090** (0.037)	0.132** (0.054)	0.088** (0.035)
<i>R</i> -squared	0.312	0.618	0.253	0.358
Obs.	1989	1989	1989	1989

Notes: For these models, boom areas were defined using a \$100 million as opposed to \$500 million threshold. Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

Table A.8: Estimates of the Effect of the Boom on Wage Rates and Employment Relative to 2006; Boom Threshold of \$100 Million

	Wage Measure					
	Mean (1)	1st Dec. (2)	1st Qrt. (3)	Median (4)	3rd Qrt. (5)	9th Dec. (6)
Boom \times 2007	0.009*** (0.002)	0.003 (0.006)	0.009*** (0.003)	0.008*** (0.003)	0.005* (0.003)	0.009*** (0.003)
Boom \times 2008	0.018*** (0.004)	0.021*** (0.006)	0.020*** (0.006)	0.021*** (0.004)	0.012** (0.005)	0.010** (0.005)
Boom \times 2009	0.029*** (0.006)	0.037*** (0.005)	0.034*** (0.007)	0.032*** (0.007)	0.022*** (0.008)	0.018** (0.007)
Boom \times 2010	0.032*** (0.007)	0.046*** (0.006)	0.045*** (0.008)	0.037*** (0.008)	0.026*** (0.008)	0.016** (0.008)
Boom \times 2011	0.040*** (0.010)	0.054*** (0.008)	0.054*** (0.011)	0.046*** (0.013)	0.031*** (0.011)	0.023** (0.009)
Boom \times 2012	0.050*** (0.012)	0.059*** (0.009)	0.064*** (0.015)	0.060*** (0.016)	0.043*** (0.013)	0.030*** (0.011)
Boom \times 2013	0.052*** (0.014)	0.063*** (0.012)	0.067*** (0.018)	0.062*** (0.018)	0.046*** (0.014)	0.033** (0.013)
Boom \times 2014	0.058*** (0.016)	0.068*** (0.014)	0.077*** (0.020)	0.070*** (0.019)	0.052*** (0.015)	0.035** (0.015)
<i>R</i> -squared	0.420	0.620	0.223	0.214	0.294	0.348
Obs.	1373	1373	1373	1373	1373	1373

Notes: For these models, boom areas were defined using a \$100 million as opposed to \$500 million threshold. Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

Table A.9: Estimates of the Effect of the Boom on Housing Relative to 2007; Boom Threshold of \$100 Million

	ln(Home Value) (1)	ln(Med. Rent) (2)	ln(Rent as % of Inc.) (3)	ln(Housing Units) (4)
Boom \times 2000	0.050* (0.026)			0.013 (0.008)
Boom \times 2008	0.021*** (0.004)	0.010*** (0.004)	-0.009 (0.006)	-0.006 (0.007)
Boom \times 2009	0.042*** (0.008)	0.014** (0.006)	-0.013* (0.008)	-0.006 (0.009)
Boom \times 2010	0.067*** (0.014)	0.017** (0.008)	-0.006 (0.011)	-0.005 (0.010)
Boom \times 2011	0.092*** (0.021)	0.024* (0.012)	-0.004 (0.012)	-0.002 (0.011)
Boom \times 2012	0.113*** (0.028)	0.037** (0.016)	-0.001 (0.013)	0.001 (0.012)
<i>R</i> -squared	0.676	0.543	0.298	0.620
Obs.	1071	918	918	1071

Notes: For these models, boom areas were defined using a \$100 million as opposed to \$500 million threshold. Dependent variables are indicated in the columns headings. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Years correspond to the center years of the 5-year estimates reported by the ACS. Standard errors are clustered at the NMA level and reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance, respectively.

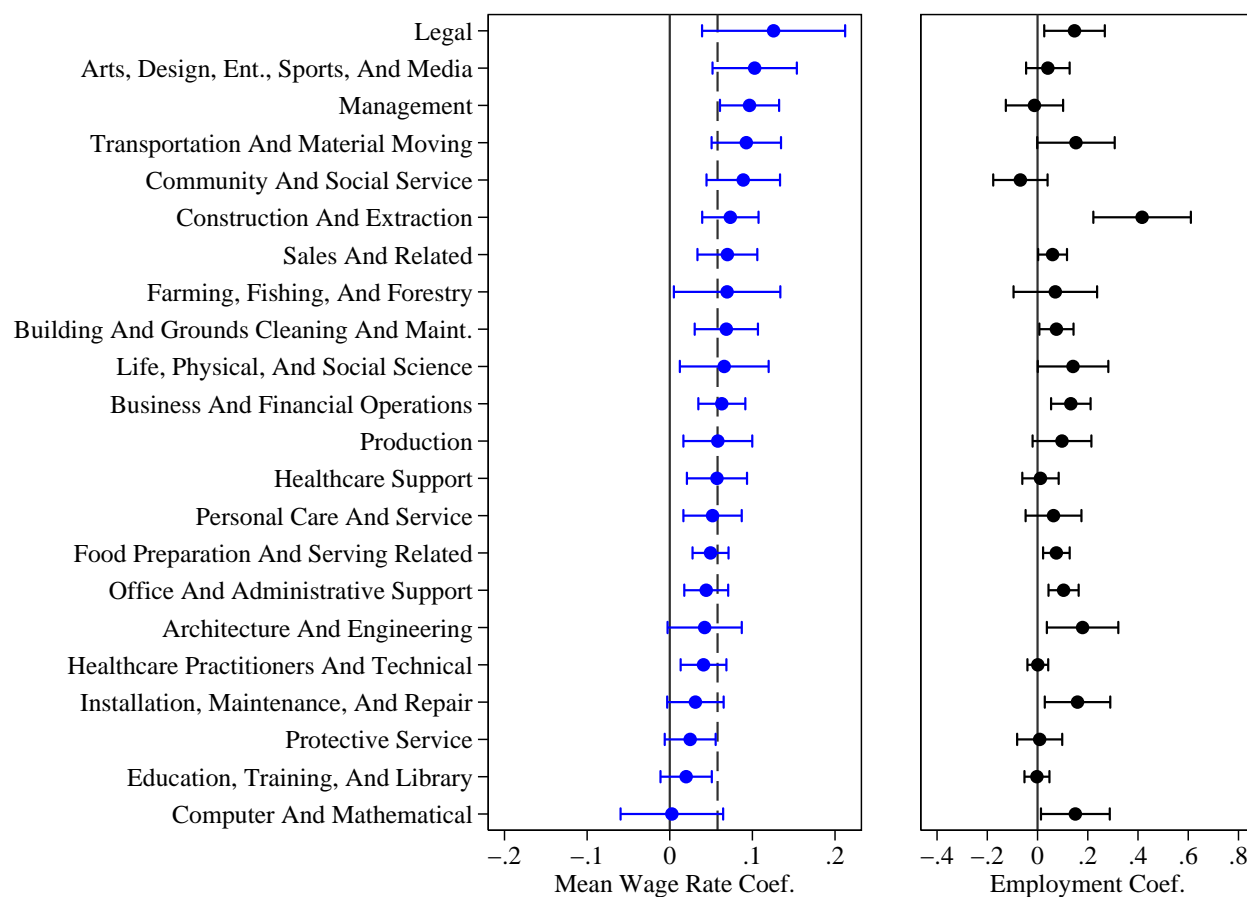


Figure A.3: Estimates of the Effect of the Boom on Wage Rates and Employment in 2014 Relative to 2006 for Each Occupational Category; Boom Threshold of \$100 Million For these models, boom areas were defined using a \$100 million as opposed to \$500 million threshold. Each coefficient comes from a separate regression with the corresponding dependent variable as indicated by both axes. The coefficients presented are those on the “Boom \times 2014” interaction terms. The vertical dashed line represents the overall estimate across all occupations (see the first column of Table A.8). The whiskers represent 95-percent confidence intervals. All specifications are based on equation 1 and include NMA fixed effects and year dummy variables. The unit of observation is an NMA and a year. Standard errors are clustered at the NMA level.