Essays in Applied Microeconomics

By

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To my parents, who did everything they could to set me up for success

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INTRODUCTION

Improving population health, educating adolescents, and reducing crime rates are all goals that economists and policy makers share. To practice evidence-based decision making, policy makers must be informed about how economic shocks affect different populations and how to target policies for optimal impact. This dissertation consists of three chapters in which applied microeconomic tools are used to study health and educational outcomes. My first chapter analyzes the effects of recreational gun use on violent crime and drug-related arrests, targeting an understudied population in the gun literature: rural Americans. The second chapter investigates the effects of a low-skill labor demand shock in rural North Dakota on educational outcomes. The third chapter examines the impact of economic conditions on an outcome strongly linked to individual health: sleep duration.

My first chapter, *Good Bang for the Buck: Effects of Rural Gun Use on Crime*, provides the first estimates of the effect of rural recreational gun use on crime. Each year, more than 10 million Americans, comprising 18% of all American gun owners, use firearms to hunt deer during restricted dates. Hunting proponents argue that long guns are not positively associated with violent crime, while the sheer magnitude of hunter activity requires this hypothesis be tested to inform gun policy design. My empirical strategy exploits variation across states in opening dates of firearm-based deer hunting seasons, which create larger increases in gun use than any other policy in existence. Combining daily crime data with deer hunting seasons spanning 20 years and 21 states, I estimate that the start of firearm season is associated with a 300% increase in long gun prevalence. Despite this enormous increase in gun use, I find no evidence of an increase in violent crime. I estimate the elasticity of violent crime with respect to recreational long gun use to be between -0.01 and +0.0003. Moreover, I estimate that alcohol-related arrests of juvenile males fall by 22% and narcotic offenses fall by 15% at the start of hunting season, suggesting that firearm hunting may have positive externalities via reducing risky juvenile male behavior.

My second chapter, *Bakken Out of Education to Toil in Oil*, uses novel datasets from the North

Dakota Department of Public Instruction (NDDPI) and North Dakota University System (NDUS), I study the effects of the North Dakota oil boom on high school graduation rates and post-graduation outcomes of seniors in North Dakota high schools using an event-study design. The oil boom sharply increased wages and employment in core-oil counties. Surprisingly, high school graduation rates of schools in core-oil counties did not decrease relative to schools in non-oil counties for either males or females. However, high school seniors responded to the oil boom by decreasing 4 year college enrollment rates by 23%. Notably, college enrollment rates also decreased for females. Estimates suggest that males and females became more likely to enter the workforce while male military enrollment rates decreased.

My third chapter, *Economic Conditions and Sleep*, uses the American Time Use Survey (ATUS) from 2003-2015 to analyze the effect of economic conditions on sleep duration. Prior work has found that increases in the employment rate cause sleep duration of individuals to fall. No previous research considers that weekday sleep behavior and weekend sleep behavior may be differentially related to economic conditions. Estimates suggest that weekday sleep duration is indeed countercylical while weekend sleep duration is procyclical. Results are driven by individuals most susceptible to economic fluctuations: minorities, single adults, and individuals with less education. Differential results concerning economic conditions and sleep by day type may be one mechanism for which to expect economic conditions to impact other sleep related outcomes diversely depending on day of the week.

Combined, these three chapters provide convincing empirical evidence that recreational policies and economic conditions can impact health and educational outcomes. My results provide no evidence that large-scale recreational gun use by rural Americans is positively associated with violent crime, while additional recreational opportunity may decrease drug and alcohol-related arrests. Strong low-skill biased labor demand shocks may impact both males and females, decreasing college enrollment rates. Improved economic conditions may decrease weekday sleep but actually increase weekend sleep, an important finding considering that medical research shows that sleep consistency matters.

CHAPTER 1

GOOD BANG FOR THE BUCK: EFFECTS OF RURAL GUN USE ON CRIME

1.1 Introduction

In 2015, firearms were used in 71.5% of US homicides, 40.8% of robberies, and 24.2% of aggravated assaults (FBI, 2016). The high rate of firearm use in violent crime has fueled a growing debate concerning the relationship between gun prevalence and violent crime. If firearms impose a negative externality (Cook and Ludwig, 2006; Duggan, 2001), then optimal gun policy should target guns and gun owners that impose the largest social costs. In this spirit, many existing gun regulations specifically apply to youths, individuals with mental health conditions or criminal records, or to specific kinds of firearms such as "assault weapons."[1] However, lack of research exploring the heterogeneity of social costs across gun owners and gun types provides limited insight for optimally targeting along other dimensions. Much of the economics literature focuses on handguns, as "they account for 80% of all gun homicides...Hence the social costs of handgun ownership are much higher than ownership of rifles and shotguns. Unfortunately, it is difficult to distinguish between the prevalence of long gun ownership and handgun ownership..."(Cook and Ludwig, 2006).

Remarkably, no studies to date have focused on potentially the largest group of gun users who claim that their guns do not increase violent crime: rural hunters with shotguns and rifles.[2] A group so powerful that Democratic President Bill Clinton went hunting after signing the Brady Handgun bill to distance his policies from hunters and so important in Midwestern swing-states that Democrat John Kerry included an Ohio goose hunt in his 2004 presidential campaign to woo rural voters.[3] This study focuses on males, who, as discussed in Section 1.3.2, comprise 89% of

[1] The term "assault weapon" is hotly debated. Some groups refer to semi-automatic rifles with detachable magazines as assault weapons, while other groups consider a firearm to be an assault weapon if the firearm has selective-fire capabilities: the ability to switch between semi-automatic, burst, or automatic firing modes.

[2] Approximately half of members in the National Rifle Association (NRA), a group that believes guns decrease crime, are hunters (Parker, 2018).

[3] As suggested by his Iowa campaign director, John Kerry went pheasant hunting in Iowa to build rapport and

U.S. hunters. We know little about the social costs of long guns, which comprise 53% of U.S. firearms (Azrael et al., 2017). While violent crime rates in urban communities are double the rate in rural communities, gun ownership rates in urban communities are only half the rate in rural areas (FBI, 2016; Azrael et al., 2017; Research, 2017). Rural individuals are disproportionately more likely to own long guns and to use firearms for hunting. Existing studies leave one of the biggest questions in the gun control debate untested: does recreational long gun use impact violent crime? Natural experiments that systematically alter gun use are difficult to find, especially in an urban context. It is plausible that two contentious claims in the gun control debate are both correct: handguns often owned for defense exert negative externalities while long guns owned for recreational purposes do not. This must be empirically tested, as Figure 1.1 shows that the presumed "innocence" of long guns may be driven by the urban skew of previous research.

This paper uses state and sub-state variation in modern firearm deer seasons from 1995 to 2015, across 21 states (covering approximately 38% of all firearm deer hunters), to provide the first evidence of the effects of rural male recreational gun use on violent and nuisance crimes. Modern firearm deer hunting is only legal certain days of the year, creating a 300% increase in male long gun use around opening season. To my knowledge, regulatory constraints on modern firearm deer seasons create larger temporary changes in aggregate gun use than any other policy in existence. This paper follows work like Lindo et al. (2018), which show that plausibly exogenous changes to recreational constraints can significantly impact crime. I use panel data from the National Incident Based Reporting System (NIBRS) to focus on daily crime in rural law enforcement agencies. My empirical strategy uses within-hunting zone (state or sub-state level) variation in firearm season access and adjusts for differences in crime across days of the panel. Falsification exercises using crime in urban law enforcement agencies illustrate that the design is not capturing other shocks that occur near the opening day of firearm deer season.

To proxy for changes in gun use, I use the number of daily arrestees who are armed. The number of armed arrestees is not itself a marker of gun crime, as it will mechanically increase

separate his stance on "hunting guns" from "assault weapons."

if more of the rural population is armed but arrested for non-violent reasons. I estimate that the number of male arrestees armed with a long gun in rural jurisdictions increases 300% upon the opening of firearm deer season. Considering overall rural arrests remain stable, this provides strong evidence that societal gun use increases. That is, the 4.2 million hunters covered by my sample who hunt during modern firearm season are interacting with society enough to be arrested (for any type of crime).

Given the enormous increase in long gun use, it is notable that estimates provide *no* evidence that violent crime increases upon opening season. On opening day, when upwards of 30% of rural males are using long guns, estimates can rule out positive effects on violent crime larger than 6% (point estimate of 0.02). Estimated effects on violent crime for the second and third day of firearm season are actually negative. Using armed arrestees as a proxy for long gun use implies an elasticity of violent crime with respect to recreational long gun use between -0.01 and +0.0003.

In rural America, firearm deer season is a popular expansion to an individual's set of recreational opportunities. How important is deer hunting? Data covering over 2.2 million absences of Pennsylvania state employees in 2016 show that males average 3,826 more vacation hours per day than females. On opening day of firearm deer season, males take *50,000* more vacation hours than females: a larger differential, by a factor of two, than any other day of the year (Figure 1.4). Firearm deer hunting could offset the negative externality of alcohol and drug consumption by causing males to substitute away from riskier leisure activities and toward hunting. Incapacitation and concentration (of social interaction) are important factors that impact crime (Jacob and Lefgren, 2003; Dahl and DellaVigna, 2009). Firearm season could have the unintended, and free, benefit of incapacitating young males similar to an after-school program while potentially reducing juvenile male concentration. My estimates suggest that alcohol-related arrests for young rural males (21 and under) fall by 22% when firearm season begins, and narcotic offenses fall by 15%. Further examination shows that the offsetting effects are driven by hunting zones that open season on a weekend, when alcohol-related arrests are typically higher.

My paper demonstrates that two key claims in the gun control debate are not mutually exclusive. It is plausible that handguns used for defensive purposes increase violent crime while long guns used in rural, recreational environments do not. The social costs of gun use may depend on the type of gun and reason for ownership. While previous literature sheds light on the effects of firearm ownership, we know almost nothing about the effects of recreational firearm use. I provide the first evidence of the crime effects of large increases in rural firearm use due to hunting season regulations. In doing so, I observe enormous, systematic fluctuations in firearm use that do not exist in any urban setting. These regulations impact 12.7 million firearm deer hunters each year and 4.3 million covered by my sample. Second, I examine an understudied sample: rural male recreational long gun users who actively use firearms. Hunters comprise up to one quarter of total firearm owners, and over half of all firearms in the United States are long guns (Azrael et al., 2017). Given that rural individuals own different firearms for different reasons than other firearm owners commonly studied in the literature, impacts on violent crime may differ.

Aside from the contributions above, this paper is meaningful for policy-makers as it provides evidence that immense changes in rural recreational long gun use have no economically significant impacts on violent crime. As this population is a large stakeholder in the gun policy debate, results suggest that policy makers should target other firearms types and owners that have a tighter relationship with violent crime. My results imply that policies that aim to restrict recreational long gun use will have no beneficial impact on crime. Additionally, my results suggest that state policy-makers could capitalize on the positive externality of firearm season on alcohol and drug related arrests by moving the opening day of firearm season to days where the counterfactual leisure activity is most likely to be alcohol-related: the weekend.

1.2 Literature Review

1.2.1 The Relationship Between Guns and Crime: a Conceptual Framework

A 2015 survey by (Azrael et al., 2017) found that 22%, or 55 million Americans, report owning firearms (with the average owner having 4.8 guns), leading to an estimate of 265 million firearms in the U.S. Given the prevalence of gun ownership and violent crime in the United States, a body of literature has attempted to estimate the aggregate relationship between guns and violent crime. I build on the framework in Kovandzic et al. (2013) to summarize key channels by which guns can impact crime. Aggregate violent crime, VC_z, in zone z are modeled as a function of gun prevalence (gun ownership, gun access, et cetera) g_z, so that $VC_z = VC(g_z)$. Guns may impact crime via the following channels:

1. Deterrence: $\frac{\partial VC_z}{\partial g_z} < 0$. Aggregate gun prevalence could deter violent crime if criminals anticipate that potential victims or helpful bystanders are more likely to be armed. Gun prevalence could exert a positive externality similar to LoJack (Ayres and Levitt, 1998) if criminals are unable to determine whether a potential victim is armed.

2. Facilitation of Crime: $\frac{\partial VC_z}{\partial g_z} > 0$. Guns may decrease the difficulty of incapacitating a victim, which may increase the expected success rate of an attack and increase crime on the extensive margin. Gun access may also escalate an argument or simple assault to a more serious altercation leading to aggravated assault or homicide.

3. Supply of Stealable Guns: $\frac{\partial VC_z}{\partial g_z} > 0$. Even guns owned by non-criminals may increase violent crime if criminals access firearms via burglary. Over 1.4 million firearms were stolen between 2005 and 2010, with handguns being the most common target (Langton, 2012).

It is likely that the relationship between guns and crime is heterogeneous (Cook and Ludwig, 2006). As stated in Cook et al. (2010), "The disparity between the demography of gun sports and of gun crime is telling: sportsmen are disproportionately older white males from small towns and rural areas, while the criminal misuse of guns is concentrated among young urban males, especially minorities." While hunting permit data from Wisconsin (Figure 1.A1b) show that juveniles also hunt at high rates, it is likely that the relationship between guns and crime is a function of individual and gun characteristics.

$$\frac{\partial VC_z}{\partial g_z} = \frac{\partial VC_z}{\partial g_z}(\text{GunType}_z, \text{GunUse}_z, \text{OwnerCharacteristics}_z)$$

GunType_z may matter, as criminals may have differing preferences over handguns, long guns, or semi-automatic weapons. Previous literature focuses on handguns because they are the primary gun used in violent crime, as criminals prefer high-caliber semiautomatic handguns that are easily concealable in a waistband (Zawitz, 1995; Cook and Ludwig, 2006). GunUse_z, whether the gun is used for offensive, defense, or recreational purposes, may also matter. Lastly, owner characteristics, $\text{OwnerCharacteristics}_z$, may impact the relationship with crime. Older and higher income gun owners may be less associated with violent crime (Cook et al., 2010), while the same may hold for individuals who legally possess a gun. In a simple case where $g_z = g_z(\text{handgun}_z, \text{long gun}_z)$, even if $\frac{\partial VC_z}{\partial g_z} > 0$ it is possible that the aggregate positive relationship is driven by $\frac{\partial VC_z}{\partial \text{handgun}_z} > 0$ while $\frac{\partial VC_z}{\partial \text{long gun}_z} \leq 0$. Current studies are hamstrung by lack of high-quality panel data on gun prevalence, much less gun type. Finding valid proxies for aggregate gun prevalence is difficult enough (Kovandzic et al., 2013; Kleck, 2004) while gun-specific proxies are even more challenging to find.

1.2.1.1 Channels Specific to Recreational Gun Use and Crime

Participation in firearm hunting requires that an individual has access to both a firearm and ammunition. While a hunter personally carries a firearm in woods, there will be an enormous increase in individuals with firearms in vehicles. One could imagine an individual who leaves his firearm in his vehicle, drinks at a bar after hunting, and escalates a bar fight (simple assault) to aggravated assault with a firearm. Moreover, any hunter who returns home and neglects to re-lock his firearm increases firearm access for all non-hunting family members or friends. From the channels listed above, firearm season could increase deterrence, enhance the facilitation of crime, and increase the supply of stealable guns that can be used in crime.

From a psychological perspective, it has been argued that hunting could desensitize individuals to committing violent acts and is “teaching children to kill” (Shapiro, 2016) similar to violent video games or movies studied by Dahl and DellaVigna (2009). This argument is a less extreme analogy to the U.S. military desensitizing servicemen and servicewomen to killing (Robinson, 2005), which may increase proclivity to violence (Rohlfs, 2010; Lindo and Stoecker, 2014). A successful hunter must consciously aim and pull the trigger to kill an animal, while even ethical kill-shot locations like the heart or lungs do not result in instant death. Deer typically run after being shot and thrash on the ground with significant bleeding. For some the guilt never leaves, while for others it "Becomes all automatic...Find target, bring rifle (or whatever) track, locate in sights...make my decision "shoot/not shoot"...based on what where, makeable shot percentage...bang...don't feel it or even hear it..." (hunter63, 2017). It is possible that desensitization to killing could transcend deer, reducing the mental costs of committing violent crimes against humans.

1.2.2 Studies on The Effects of Aggregate Gun Ownership

Much of the economics and criminology literature has attempted to estimate the aggregate sign and magnitude of $\frac{\partial VC_z}{\partial g_z}$. Causal identification is hindered by potential reverse causality: areas with increases in violent crime may experience increases in gun prevalence. Additionally, other factors may influence both gun prevalence and violent crime. Cook and Ludwig (2006) estimate the social costs of gun ownership using within county variation in estimated gun prevalence. Using fraction of suicides committed with a firearm as a proxy for gun ownership, the authors estimated an elasticity of homicide with respect to gun prevalence of +0.1 - +0.3. The authors noted that the social costs of handguns were almost certainly higher than the social costs of long guns, as handguns are the most common gun used in violent crimes and suicides. Duggan (2001) estimated a similar elasticity of +0.2 when using firearm magazine sales as a proxy for gun prevalence. However, Kovandzic et al. (2013) argue that the preceding studies use proxies that are valid for cross-sectional gun prevalence but invalid proxies for changes in prevalence over time. Using an instrumental variables strategy, the authors find that gun prevalence has a negative (deterrent) effect on crime. Other studies find no evidence of a causal relationship between guns and crime (Moody and Marvell, 2005; Kleck and Patterson, 1993).

1.2.3 Studies on The Effects of Gun Policy

What do we know about the effects of gun policies? In 2018, the RAND Corporation's Gun Policy in America initiative published a review of quasi-experimental evidence (from 63 papers meeting inclusion criteria) on 13 classes of gun policy (Morral et al., 2018). The study summarized that background checks and mental-illness restrictions may reduce violent crime while stand-your-ground laws and concealed-carry laws may increase violent crime. Child-access prevention (CAP) laws were found to decrease suicides and firearm-injuries among children. The authors state, "Notably, research into four of our outcomes was essentially unavailable, with three of these four outcomes- defensive gun use, hunting and recreation, and the gun industry-representing issues of particular concern to gun owners or gun industry stakeholders." My study aims to fill part of the research void concerning hunting and recreation, not as an outcome, but as a lever of plausibly exogenous variation in long gun use.

Safe-storage laws have been passed by states to reduce accidental gun deaths, especially among minors. Lott and Whitley (2001) found that safe-storage laws may increase crime against noncriminals while having no beneficial impact on accidental gun deaths or suicides while Cummings et al. (1997) find they decrease accidental firearm deaths among children with no statistically significant impact on firearm homicide. More recent work has found that CAP laws decrease nonfatal gun injuries among children (DeSimone et al., 2013) and may decrease juvenile homicides committed with a gun by 19% (Anderson et al., 2018). On a similar motive to limit firearm access to high-risk youths, firearm age restrictions have been passed. Though homicide rates among young males are high, age restrictions on handguns may have no significant impact on homicide rates (Rosengart et al., 2005).

One channel by which guns could decrease crime is by deterrence. If right-to-carry laws increase noncriminal carry rates, violent crime could be thwarted. Work by Lott and Mustard (1997) suggesting that right-to-carry laws reduce violent crime was quickly followed by opposite or null results (Dezhbakhsh and Rubin, 1998; Duggan, 2001; Black and Nagin, 1998; Ludwig, 1998; Rubin and Dezhbakhsh, 2003; Ayres and Donohue III, 2003; Aneja et al., 2011). Related to handguns and concealed-carry laws, Gius (2015) found that firearm homicides decreased after the passage of the Brady Handgun Bill. Similar to the rationale of right-to-carry laws, "stand your ground" laws were passed by states to expand rights to use deadly force within one's home, which could theoretically deter crime. Cheng and Hoekstra (2013) found that "stand your ground" laws have no deterrent effect on burglary or aggravated assault, but lead to an increase in murder.

Policies concerning ease of firearm access have also been studied. Policies that delay the time between purchasing and receiving a firearm, so called "waiting periods", have no impact on homicides but may decrease gun related suicide (Edwards et al., 2018). Knight (2013) found that guns used in crimes are often sourced from states with weaker gun laws. In this vein, Dube et al. (2013) find that access to U.S. based assault weapons increased homicides and violent crime in Mexico. However, no cohesive evidence exists concerning the effects of a assault weapons in the U.S. (Morral et al., 2018). Others have been concerned that the "gun show loophole" has made it easier for criminals to access firearms without undergoing background checks. Matthay et al. (2017) found that gun shows in states with less restrictive gun control laws may cause a short-term increase in firearm injuries, driven by interpersonal violence. However, Duggan et al. (2011) studied 3,400 gun shows in California and Texas, finding no evidence of increases in suicides or homicides. Other studies have examined the impact of permit to purchase laws, which require an individual to obtain a permit before purchasing a firearm. Webster et al. (2014) found that the repeal of permit to purchase in Missouri increased the homicide rate. Using a synthetic-control method, Rudolph et al. (2015) reported that the permit-to-purchase law reduced Connecticut's firearm homicide rate by 40%.

1.2.4 Studies on The Effects of Gun Use

While most of the literature focuses on firearm ownership or effects of gun policies, little is known about the effects of gun use. The reasons for this are practical: systematic data covering state or county level gun ownership are limited while ownership can be proxied for by using firearm magazine subscriptions or fraction of suicides by firearm (Duggan, 2001; Cook and Ludwig, 2006).

Unfortunately, data is even more sparse concerning gun use and especially temporary fluctuations in gun use. One way to study the effects of temporary changes in gun use is to find a natural experiment that plausibly impacts gun use. Jena and Olenski (2018) study NRA conventions, which may temporarily decrease firearm use if gun-users are attending conventions (and don't bring firearms). The authors found that gun-related injuries decrease during NRA convention dates, suggesting that even experienced gun owners are at risk of gun-related injury.

Evidence of rural male firearm use and violent crime is much more sparse. Conlin et al. (2009) study deer hunting accidents in Pennsylvania, finding that minimum antler requirements may lead hunters to take more calculated shots and reduce hunting accidents. These studies provide evidence on accidental injuries, but leave questions about whether violent crime is impacted. According to a Pew Research poll, 50% of NRA members hunt (Parker, 2018). Yamane (2017) propose that recreational use of guns like hunting are a driver of the strong gun culture in America. Glaeser and Glendon (1998) suggest that gun ownership is highest where police accessibility is the lowest and for individuals who distrust the government. The strong gun culture of rural America is illustrated in a 2017 Pew Research poll finding that 58% of rural households own a gun versus 19% of urban households (Igielnik, 2017). Of these rural gun owners, 47% reported that they obtained their first gun before the age of 18. Rural gun owners were 23 percentage points more likely to say that the right to own guns was "essential to their own sense of freedom." Moreover, Tables 1.3 and 1.4 show that rural gun owners are much more likely to own long guns, which are most commonly used for hunting, unlike handguns which are most commonly used for self-defense. The strong gun culture of rural America makes the effects of rural gun use on violent crime an imperative area to study to further understand the unique perspective that rural Americans hold on gun control.

The net effects of increased gun access on violent crime due to firearm season are ambiguous. Sharp increases in gun carry rates of prime-age males and youths may increase violent crime or escalate the intensity of arguments above the counterfactual in which firearms were not present. Additionally, easier access for non-hunting youths in a hunting household may increase violent crime. Evidence suggests that child access prevention (CAP) gun control laws reduce gun carrying rates and rates of weapon-related threats or injuries among youths (Anderson and Sabia, in press). However, hunting is a time consuming activity that may reduce crime via voluntary incapacitation, similar to violent movies (Dahl and DellaVigna, 2009). Additionally, Jacob and Lefgren (2003) suggest that activities that incapacitate *and* deconcentrate juveniles will have the most beneficial impact on juvenile crime. Males may deconcentrate when deer hunting in the woods, which may decrease crimes associated with social interaction.

1.3 Institutional Background

1.3.1 Different People, Different Guns, Different Reasons

Firearms are designed for different uses: self-defense, hunting, recreation, etc. Previous literature heavily focuses on handguns because they are the primary gun used in violent crime, as criminals prefer high-caliber semiautomatic handguns that are easily concealable in a waistband (Zawitz, 1995; Cook and Ludwig, 2006). Handgun owners who own no other guns almost exclusively report self-defense as a reason for ownership (Table 1.4), while Wright and Rossi (1986) suggests that offensive firearm use is more correlated with defense than recreational ownership. Recreational long guns are more likely to be legally possessed than handguns, as handguns are the most common type of stolen gun while semi-automatic handguns are common in illicit markets (Langton, 2012; Koper, 2014).

Table 1.3 reports firearm ownership by demographic, as estimated by the 2015 National Firearms Survey (Azrael et al., 2017), showing stark differences in ownership patterns of rural versus urban individuals. Rural individuals are more than twice as likely as urban individuals to own a firearm (33% versus 15%). While rural individuals are actually less likely to report owning only a handgun, they are three times as likely to report owning only a long gun and 2.7 times more likely to report owning both a handgun and long gun. Gun differences are just as stark when broken out by race. While black individuals are approximately half as likely to own a gun as white individuals, they are actually 1.6 times more likely to own only a handgun. While 6% of whites own only a long gun, only 1% of blacks do so. Table 1.3 makes it clear that urban and black individuals are demonstrably more likely to own handguns, which are primarily used for protection against humans. The economics and criminology literature has focused on this subset because urban and black violent crime rates are significantly higher than the population average. For example, O'Flaherty and Sethi (2010) studied why black Americans are seven times more likely than white Americans to murder someone. Evans et al. (2018) studied the emergence of crack cocaine markets in urban areas and the long run impact, via increased gun prevalence, on young black male murder rates. However, current literature has left long gun toting white and rural individuals understudied. This group is significantly more likely to use firearms for hunting or other sporting purposes.

Modern firearms for hunting fit in three primary groups: muzzleloaders, rifles and shotguns. A muzzleloader is a single-shot rifle or shotgun that is loaded from the muzzle. In most states, modern shotguns and rifles are more popular due to ease of use. A modern rifle has a rifled barrel (helical grooves in the bore) to spin the bullet as it exits the firearm, increasing accuracy for long-range targets. A hunter with a rifle can execute an ethical kill shot on a deer from over 300 yards (three football fields) away. A shotgun typically has a smooth bore barrel, providing a more limited ethical kill range. Shotgun shells often include numerous pellets that spread around the target, with the spread increasing with distance. This increased margin-of-error is one reason why shotguns are often touted as being better for home-defense than a rifle or handgun. Shotgun deer hunters are typically restricted to using shotgun slugs, large single-bullet projectiles, which provide an ethical kill-range for a deer around 75 yards.

The iconic hunting gun might be a single-shot bolt action rifle or a single-shot shotgun, which may mislead one to think that hunting firearms are inherently innocent. But U.S. crime data, discussed in Section 1.4.4, show that the share of violent gun crimes committed with long guns increases linearly as the population of the law enforcement jurisdiction decreases (Figure 1.1). It is clear that long guns are commonly used in crime, just not in urban areas. Furthermore, many rifles and shotguns used for hunting are semi-automatic, defined as autoloading firearms that fire one time per trigger pull (pump-action shotguns can hold multiple shells but are not semi-automatic because a hunter must pump between trigger pulls). The public is much more concerned about these weapons. These guns have been subject to confiscations in other countries such as the 1996 Australian gun buyback program, which confiscated semi-automatic and pump-action shotguns. This buyback may have reduced suicides and homicides (Leigh and Neill, 2010; Chapman et al., 2006).

In particular, AR-15s and AR-15 variants have been the most hotly debated firearm of the last 30 years. Even the name itself is debated, with some calling it an "assault rifle" or "assault-style rifle" while others and the gun industry call it a modern sporting rifle. AR-15 rifles and variants have been heavily publicized due to use in tragic mass shootings (Parkland, Florida; Las Vegas, Nevada; Newtown, Connecticut; etc.).[4] The 1994-2004 Federal Assault Weapons Ban targeted semi-automatic rifles like the AR-15: semi-automatic firearms with a pistol grip, detachable magazine, et cetera. While objective survey data do not exist, a study by the National Shooting Sports Foundation reported that 27% of hunters have used a modern sporting rifle (or "assault-style rifle") to hunt game. Semi-automatic shotguns are often preferred by hunters who desire superior recoil-reduction systems (less "kick"), which are especially beneficial for smaller hunters. Similarly, the accurate AR-15 is lightweight with an adjustable stock and limited recoil which benefits hunters with smaller frames. The ability to follow a target with a semi-automatic firearm with limited recoil makes the weapon popular for varmint, coyotes, wild hogs, et cetera. Semi-automatic rifles and shotguns are common hunting implements, implying that we cannot *a priori* characterize hunting firearms as innocent.

1.3.2 U.S. Hunting Participation

Hunting is a popular recreational activity throughout the United States, especially in rural areas. Data from the US Fish, Hunting, and Wildlife-Associated Recreation (FHWAR) survey

[4] https://www.nytimes.com/interactive/2018/02/28/us/ar-15-rifle-mass-shootings.html; https://www.usatoday.com/story/news/2017/11/06/ar-15-style-rifles-common-among-mass -shootings/838283001/

in Figure 1.2 shows hunter participation rates by state.[5] Participation rates range from a low of 1% in California to a high of 20% in South Dakota, Alaska, and Louisiana. Notably, data from the 2011 FHWAR survey show that 89% of all hunters are male. Nationwide, approximately 11% of males and 1% of females over the age of 16 hunted in 2011. While the FHWAR only surveys individuals above the age of 16, data from Wisconsin (1.A1b) shows that hunting participation increases at age 10 and reaches a local maximum at age 15. As of 2011, the US had 13.7 million hunters (above the age of 16) who spent 282 million days in the field. Of the 13.7 million hunters in the US, 11.6 million are big game hunters. Big game hunters averaged 18 days in the field. Deer hunting is the backbone of American big game hunting, with 10.9 million deer hunters in the US. These hunters spent $33.7 billion on guns, equipment, trips, land, and other hunting expenses (Table 1.1).

While hunting participation rates vary by state, rates also vary significantly by rural versus urban status. Table 1.2 shows that hunter participation rates range from 3% in Metropolitan Statistical Areas (MSAs) to 18% in areas outside of an MSA. Approximately 94% of hunters are white and 47% of hunters have less than or equal to a high school education. The amalgamation of these summary statistics clearly show that white rural males are the dominant hunting demographic.

To hunt deer, an individual must purchase a state-specific hunting license. Most individuals must pass a hunter education course before purchasing a hunting license (older hunters may be grandfathered in). However, no firearm background check is required to purchase a license that is valid for firearm season. A hunter must purchase a deer tag (or permit) for each deer they intend to harvest and must bring it with them when hunting. Immediately after the kill, a hunter must "tag" their deer. This involves filling out information related to the kill and attaching the paper to the deer. The tag must remain on the deer until it is processed or butchered. It is possible that the formal paperwork required to hunt may discourage participation of individuals who illegally possess a firearm.

[5] The FHWAR survey is a joint effort between the US Fish and Wildlife Service and the US Census to estimate recreational activity across the U.S.

1.3.3 Deer Hunting Seasons

A typical state has a multitude of deer hunting seasons each year. Archery season typically open in early fall and runs to early January of the following year. Seasons with relatively little participation are often scattered throughout late fall. These include special seasons for muzzleloaders, flintlocks, or even spear-hunting (in Alabama).[6] A youth weekend often precludes the main firearm season by a week or two and is usually limited to hunters under the age of 15 (supervised by an adult at least 18 or 21 years old, depending on the state). The main firearm season (often called "main season", "traditional season", or "modern firearm"), the season used in this study, typically starts between October and December (Figure 1.A3 illustrates opening dates for 2015). Table 1.2 shows that 12.73 million (93%) U.S. hunters use rifles and shotguns, which are the key implements of "modern firearm" seasons. For example, from 2005-2015, hunters in Wisconsin harvested 300,000-500,000 deer per year. Approximately 70% of all deer are harvested in the 9 day firearm season with over 100,000 deer harvested on opening weekend.

Even during deer season, hunting is not allowed all hours of the day. A typical hunting time table allows a hunter to kill between 30 minutes before sunrise to 30 minutes after sunset. Deer are a crepuscular animal, meaning that they are most active during dawn and dusk. This incentivizes hunters to be in the woods before sunrise or late in the evening. Deer harvest data from Ohio show that the majority of kills in the first 5 days of firearm season are reported in the morning or evening (Figure 1.A2b). Figure 1.A2a uses data from the American Time Use Survey to show that hunters average 5-6 hours in the field on days in which they hunt between October and January (main deer seasons). Similarly, state-level data from Wisconsin hunter surveys show that hunters average 4.12 hours per trip, while this number is certainly higher at the start of firearm season. If a hunter is successful, he must either transport his kill to a butcher or process the deer himself. Skinning and processing a deer can take the hunter another 4-5 hours. Combined, these statistics show that hunting has the potential to crowd out other uses of one's time.

[6]A flintlock (introduced in the 17th century) and muzzleloader season often target hunters who appreciate hunting for its heritage and tradition.

1.3.4 Discontinuous Hunting Activity

As seen in Figure 1.3, short season windows coupled with hunter anticipation create large discontinuities in hunting activity on opening day. Firearm deer seasons induce a discrete jump in hunter activity on opening day for a variety of reasons.

1. The stock of deer is at its peak because few have been harvested (some deer are harvested in the aforementioned seasons that preclude the main firearm season). If a hunter wants to optimize his success rate, he should hunt when the stock of deer is highest.

2. Deer can be "pressured" when hunter activity is high. Widespread increases in human activity can impact deer behavior. This change in deer behavior can reduce a hunter's success rate, incentivizing an individual to hunt while the woods are fresh.

3. Firearm deer hunting is popular and restricted season dates create anticipation. Newspapers and magazines like Field & Stream or REALTREE often advertise tips for opening day (Carpenter, 2018).

While deer hunting activity is discrete, hunters certainly prepare weapons and ammunition in the days before opening season. The constrained nature of firearm seasons provides a large change to recreational opportunities that may lead hunters to substitute away from other leisure activities or risky behaviors.

1.4 Data

In order to study how shocks to gun carry rates due to firearm deer season impact violent crime, I combine high-frequency crime data with finely delineated deer regulations.

1.4.1 Deer Season Regulation Data

I construct a novel dataset of historical modern firearm deer season dates. Hunting season dates are determined by state agencies. However, states are often divided by wildlife management units (WMUs) that may have different opening season dates. Primary sources of data are historical state-specific hunting regulation digests and Freedom of Information Act (FOIA) requests form state game commissions or natural resource departments. Data for some states were obtained via phone calls with state deer project coordinators. Missing years of data are imputed using reference dates from the Quality Deer Management Association (QDMA) Whitetail Report (QDMA, 2017). The majority of states have one primary firearm season. If a state has multiple main firearm seasons, the first firearm season of the year is used. Treatment is defined by "zone," the largest zone within a state that has the same opening firearm season date. For most states the treatment zone is equivalent to the state, as all WMUs share the same opening date. Other states, like South Dakota, may be comprised of multiple treatment zones of varying opening dates. As an example, Figure 1.A3 provides state-level opening firearm deer season dates for 2015. Opening firearm dates in the sample range from October 24 in Montana to December 5 in Iowa. States open firearm season on different days of the week: Monday, Friday, Saturday, and Sunday.

1.4.2 Deer Hunting Data

I use the US Fish, Hunting, and Wildlife-Associated Recreation (FHWAR) survey for summary statistics concerning hunters. The FHWAR survey has been administered every 5 years since 1955. Survey questions are designed by the US Fish and Wildlife Service while data is collected by the US Census Bureau. I primarily use the 2011 FHWAR, which provides state-level estimates of hunting participation rates.[7] The survey includes information on recreational time use and includes demographic traits of hunters like sex, age, race, and income. The survey also splits estimates by type of game, allowing specifics insights into deer hunting.

I supplement FHWAR data with deer harvest report data from Wisconsin and Ohio. Harvest report data are constructed from deer tags. Some states require all hunters to fill out deer tags and report their harvest to state agencies. These harvest datasets include the date of every reported deer kill (Ohio includes the time-of-kill and age of the hunter). Wisconsin also includes how many

[7]The FHWAR became more limited in 2016, as the survey was reduced to a nationally representative survey.

hours a successful hunter hunted on the day of their kill. Deer harvest report data from Wisconsin clearly show a first stage discontinuity in hunter activity on the first day of the 2017 firearm season (Figure 1.3). Prior to firearm season, Wisconsin hunters harvested less than 2,000 deer per day. Hunter activity abruptly increased on opening weekend of firearm season, when hunters harvested 100,000 deer. Combined with hunter success rates from the Wisconsin DNR, these data can be used to estimate the scale of hunter activity upon opening season.

1.4.3 Granular Employment Data

Recreational opportunities that are only available certain days of the year may be important factors for whether employees take vacation leave or sick leave. However, almost all large scale employee absence data is aggregated, such as at the monthly level. To provide additional evidence of the important ramifications of deer season regulations, I submitted a FOIA request to Pennsylvania for microdata of all absences of state employees. The data cover over 2.2 million records of employee absence in 2016 and includes the date of absence, gender of employee, and type of absence (annual-vacation leave or sick leave). I collapse observations by day-of-year and gender, and take the difference between male and female vacation hours. The male-female differential in vacation hours signals relative absenteeism while netting out factors, like holidays, that impact both genders. As shown in Figure 1.4, the male-female differential of vacation hours is *significantly* more pronounced on the first two days of firearm season than any other days of the year, providing strong evidence that deer hunting regulations have considerable effects on male time-use.

1.4.4 Crime Data

The main source of crime and arrest data is from NIBRS (FBI, 2009), which comprises data collected by US law enforcement agencies and aggregated by the Federal Bureau of Investigation (FBI). NIBRS has three key benefits for this study. First, the data includes the date, time, and location of the crime. Second, the data provides a population group underlying the respective law enforcement agency which can be exploited to focus on rural jurisdictions. Third, NIBRS details whether an offender was armed with a firearm during a crime and distinguishes between rifles, shotguns, and hand guns. This is relevant because the majority of firearm deer hunters use a rifle or shotgun. One limitation of NIBRS is that state coverage is incomplete, which limits the sample for analysis. By 2012, 32 states were certified to submit NIBRS data to the FBI (JRSA, 2018). This study uses a sample of 22 states that have adequate coverage.

I use NIBRS data from 1995 to 2015, collapsing crime data into zone-date cells. As hunter participation rates are higher in rural areas than urban, I split the analysis to focus on crime in rural areas, defined as law enforcement agencies covering less than 25,000 individuals. All jurisdictions with less than 25,000 individuals are collapsed into a hunting zone-day cell. Results are robust to other population-based definitions of rural. I also split analysis by sex of the offender or arrestee because approximately 90% of deer hunters nationwide are male. NIBRS offense files include data on Group A offenses like violent crime and weapon law violations. Data concerning Group B offenses like driving under the influence are only available in arrest files. An advantage of arrest data over offense data is that sex of the arrestee is always given while sex of the offender is often missing. However, offense data may provide a more complete and contemporaneous picture of daily crime because not all crimes lead to an arrest. I show that results concerning violent crime are robust to using either the arrest or offense files.

1.4.5 Measures of Gun Use and Crime

Recreational survey data from the US FHWAR show that over 10 million Americans firearm deer hunted in 2011, which directly implies that over 10 million Americans carried and used long guns during firearm deer season. However, no data exists to estimate daily firearm carry or use rates. Additionally, "societal use" is arguably more important. If 50% of rural males are armed on opening day versus 10% on a typical day (a 400% increase in firearm use) but these hunters walk from their farm to their woods and back without interacting with society, then it might be less surprising to find that recreational firearm use has no impact on violent crime. We would expect firearms to have a larger impact on violent crime if individuals actually interact with society while armed with a firearm. NIBRS arrest data denote whether an arrestee of any kind is armed, which does not imply that a gun crime has occurred (an individual may be armed during a DUI or property crime). To proxy for changes in firearm use, I use the daily number of arrestees who are armed. While this number will certainly understate the level of armed individuals, percent changes in the number of armed arrestees provide an estimate of changes in firearm usage rates if the proportion of armed individuals who are arrested remains the same. I will further break out results by arrestees armed with a long gun versus those armed with a handgun.

I use two different measures for daily violent crime: incidents and arrests. An advantage of arrest data is that the gender and age of the arrestee is always denoted and the type of gun used in the crime will be more accurate than that in the incident file. But not all violent crime incidents lead to an arrest in general, and especially on the same day that the incident occurred. Additionally, using incident data should mitigate concerns of potential changes in law enforcement effort due to deer hunting regulation (as an assault victim may report the incident to the police even if the offender is not arrested). Given that benefits exists for using both incidents and arrests as outcomes, I show that results are robust to using either as an outcome.

My main measures of crime are violent crime incidents or arrests. Using definitions of the Federal Bureau of Investigation (FBI), I define daily violent crime as the sum of all homicide, aggravated assault, rape, and robbery arrests or incidents. Aside from violent crime, a key outcome of interest related to firearm use is weapon law violations: illegally carrying a concealed weapon, unlicensed weapon, unregistered weapon, using suppressors (silencers), et cetera.

As firearm deer season is a popular recreational activity, I focus on crimes that are likely to be related to risky leisure behavior. First, I aggregate all alcohol-related arrests together (incident data is not taken for alcohol-related offenses): driving under the influence (DUI), disorderly conduct, liquor law violations, and drunkenness. Second, I use the number of narcotic arrests or offenses. These include incidents of consuming, dealing, transporting, or making drugs.

1.5 Empirical Strategy

Identifying variation for my research design arises from within-zone variation in season access (whether firearm season is open) over time, after absorbing fixed effects that account for seasonality of crime. Y_{zt} denotes the number of reported crimes in rural jurisdictions in hunting zone z on panel date t. The indicator for *Season* is equal to 1 on the day of opening season. Although not listed, I include dummies for event-time days leading up to and lagging opening season to study potential lead-up and dissipation of effects. Hunters typically have guns and equipment prepared a few days before opening day, as it is popular to hunt at dawn to capitalize on the additional movement the crepuscular animal has during twilight hours. As hunting is most popular opening day, dissipating effects should be observable in the lag terms. As zone-day cells are count data of crimes with a significant number of zeros, I estimate specification (1.1) with Poisson models. To account for overdispersion of the dependent variable, sandwiched standard error estimates are used and are clustered by zone level to account for correlation of the error term within a zone over time (Cameron and Trivedi, 2005). While preferred estimation uses Poisson models, Tables 1.A5-1.A8 show that results are widely robust to estimation using linear probability models.

$$\mathbb{E}[Y_{zt}|Season_{zt}, \alpha_z, X_t] = exp(\beta_0 Season_{zt} + \alpha_z + \boldsymbol{\delta X_t}) \tag{1.1}$$

My baseline specification includes zone fixed effects, which absorb time invariant heterogeneity of each zone so that estimates are identified from within hunting zone variation to season access (whether firearm deer season is open). To account for seasonality of crime throughout a year and aggregate year-to-year changes, week-of-year fixed effects and year effects are included. While opening days are spread across the week, many zones open on Friday or Saturday, when alcohol-related crime may be intensified. I include day-of-week fixed effects to absorb these patterns in crime. Therefore, my baseline specification identifies the impact of firearm deer season after accounting for expected differences in crime on that day of the week and time of year.

Though unlikely, due to the wide spread of zone-specific opening days throughout the year, it is possible that the baseline model neglects the effects of holidays or other factors that may be correlated with zone-specific opening days. To ameliorate this concern, I enrich my specification to include zone fixed effects and day-of-panel fixed effects. Using within-zone variation, estimates identify the effects on crime associated with firearm season beyond what would be expected on that day of the panel (or day-of-year-by-year). One remaining concern is that the unit of analysis is the zone-day count of crime, which aggregates daily counts of reported crime from all agencies in the zone. However, agency reporting has generally increased over the time-frame of this panel while not all agencies report to NIBRS every month. To account for the change in zone composition that may change month-to-month, I estimate another model that includes day-of-panel fixed effects and zone-by-month-of-panel fixed effects. In this specification, effects are estimated by comparing within-zone crime on opening day to crime on other days of the respective month, after accounting for average changes in crime on that day of the panel. My preferred specification is the richest specification, which includes day-of-panel fixed effects and zone-by-month-of-panel fixed effects. While this specification is used for all figures, Tables 1.5-1.6 show that estimates are robust across all three models.

1.6 Results

1.6.1 Effects of Firearm Season on Gun Use and Violent Crime

It is obvious that the number of rural armed males skyrockets around the opening of firearm deer season. If 700,000 firearm deer hunters were actively hunting in Wisconsin during a 9-day season, then 700,000 individuals were armed with a weapon because one cannot firearm hunt without a firearm. However, an important factor with implications for violent crime is the degree to which a hunter interacts with society. A hunter who is a farmer and walks to his woods and returns carries a gun but has no interaction with society. As explained above, the number of armed arrestees may proxy for societal gun prevalence, as individuals must interact with society enough to be arrested.

Figures 1.5a and 1.5b graphically illustrate results for zones that open firearm season on a Monday. The figures plot the mean of rural armed arrestees and violent crime arrests by day-of-week, split by whether firearm season is open or not. Figure 1.5a shows that rural zones arrest less than one armed individual per day outside of firearm season. This number is eight times higher the first day of firearm season. Outside of firearm season, these rural zones average less than two armed arrestees between Monday and Wednesday. However, these zones arrest almost 18 armed individuals during the first three days of firearm season. This figure provides undeniable first stage evidence of an increase in rural male gun prevalence.

Remarkably, no such disparity in violent crime is visible during the first few days of firearm season relative to days outside of firearm season. Figure 1.5b shows that rural zones actually average *less* violent crime arrests on opening Monday and throughout the rest of the week. Figures 1.A4a and 1.A4b show similar patterns for hunting zones that open season on a Saturday. A potential concern is that another mechanism, other than firearm season, could be driving the increase in armed arrestees. Figures 1.A5a and 1.A5b show armed arrestee and violent crime data for urban jurisdictions, which have much lower hunting participation rates than rural jurisdictions, showing that no such increase in armed arrestees exists for urban jurisdictions.

Figure 1.6 graphically illustrates Poisson estimates of specification 1.1, in which the model includes day-of-panel and zone-month fixed effects.[8] The figure presents estimates in event-time by day relative to the day of opening season. Estimates suggest that there are 250% more armed arrestees on opening day of firearm season, which aligns with the nonparametric, graphical evidence above. There is evidence of a lead-up in armed arrestees in the days prior to season opening, consistent with individuals preparing their weapons in advance of opening day. Patterns in armed arrestee increases follow intuition. Increases peak on opening day, when hunting participation (and therefore long gun prevalence) is highest, and magnitudes slowly decline throughout opening week. The pattern in armed arrestees is remarkably similar to deer harvest data

[8]For Poisson estimates, percent changes are interpreted as $(e^{\beta} - 1)$ x 100%.

from Wisconsin in Figure 1.3. While the number of armed arrestees increases significantly, Figure 1.6 provides no evidence that overall number of males arrests changes. This is supportive evidence of internal validity, suggesting that law enforcement efforts are not systematically changing open opening season. If there is a 250% increase in male armed arrestees but no increase in number of male arrests, this simply implies that arrested males are more likely to be armed for violent or non-violent reasons.

One potential threat to the validity of my design would be any other policy or shock that aligns with the opening day of firearm deer season and impacts crime. Firearm hunters almost exclusively hunt with shotguns or rifles, which are long guns. Any concerns that my design is picking up effects from non-hunting policies should be ameliorated by Figure 1.7, which shows that the entire increase in armed arrestees is driven by long gun prevalence. Estimates suggest that the number of arrestees armed with a long gun is 300% higher on opening day, with similar lead-up effects and dissipation effects as found above. Even a week after firearm season opens, the number of long gun armed arrestees is 50% higher. These patterns provide strong evidence that my design is isolating the effects of hunting policies.

Given the strong evidence of an immense and persistent increase in recreational long gun prevalence, it is striking that Figure 1.8 provides *no* evidence of an increase in rural male violent crime incidents. On opening day, when long gun prevalence is 300% higher, the estimated effect on rural male violent crime offenses is economically and statistically insignificant (point estimate of 0.003). Point estimates for the second and third day of firearm season are actually negative. Figure 1.8 shows that for all days surrounding the beginning of firearm season, estimated effects on violent crime consistently hover around zero. Any potential concern of population in-migration to rural areas during hunting season (as urban or suburban hunters access woods in rural areas) would place an upward bias on violent crime estimates. As shown in Figure 1.A6a, results are robust to using violent crime arrests.

Results in Table 1.5 show that estimates on long gun prevalence and violent crime are remarkably stable across specifications that flexibly alter fixed effects. In each specification, estimates suggest that long gun prevalence on the first two days of firearm season increases 290%-332%. Corresponding estimates on violent crime range from -.1% to .5%, with standard errors that rule out increases larger than 4%-5.8%. One could claim that armed males are so incapacitated (by hunting many hours) the first few days of season that violent crimes do not increase. Voluntary incapacitation should be highest on opening day (when hunting hours peak) and dissipate the following days. If incapacitation dissipates faster than long gun prevalence, we might expect lagged effects on violent crime. However, results in Figure 1.8 and Table 1.5 provide no evidence of lagged effects on violent crime.

It is widely asserted that young males are a high-risk group that should not be given access to guns. This assertion motivated federal minimum age requirements for purchasing guns and the passage of child access prevention laws. Cook et al. (2010) highlight that "sportsmen are disproportionately older white males from small towns and rural areas, while the criminal misuse of guns is concentrated among young urban males, especially minorities." However, Figures 1.A1a and 1.A1b show that young and old hunt at relatively similar rates (5% of individuals 16-24 years of age versus 7% of those 45-64 years of age). This begs the question of whether increased recreational gun access amongst *young* rural males increase violent crime. Surprisingly, Figure 1.9 provides no suggestion that this is the case. When long gun prevalence amongst young males skyrockets upon opening season, violent crime incidents remain stable for rural males 21 and under.

Previous literature shows that incapacitation may impact a male's propensity to commit crimes (Jacob and Lefgren, 2003; Dahl and DellaVigna, 2009). As shown using DNR and ATUS data, hunters spend a significant amount of time in the field. Do sexual assaults decrease when male hunters are busy? Estimates in Table 1.A2 provide no convincing evidence that reports of sexual assault decrease after firearm season opens. Additionally, there does not appear to be any impact on reports of simple assault or intimidation. Considering that a large portion of males that hunt in rural areas are systematically incapacitated during the opening of firearm season while assaults do not decrease provides support for the argument that males who hunt may on average be low-risk individuals.

1.6.2 Effects on Weapon Law Violations

While recreational long gun use may not increase violent crime, individuals may commit less serious offenses like weapon law violations. Indeed, estimates in Table 1.A2 provide strong evidence that weapon law violations increase about 28% the first two days of season. While young males may have less maturity than older males, states require hunters under certain ages to pass hunter safety courses. These courses may familiarize young hunters with local weapon laws or ingrain a deeper respect for proper firearm use and carrying. Older hunters are grandfathered out of hunter education courses and may lack up-to-date knowledge on local firearm laws. Estimates in Figure 1.10 show that firearm season induces an economically significant increase in weapon law violations for individuals 40 years of age and older, while no evidence exists of an increase in weapon law violations for males 21 and under. This may suggest that hunter safety education courses are successful, though further study is required to make this assertion. Alternatively, older males may be more likely to have a criminal record and weapon law violations may be driven by illegal firearm possession. Firearm deer hunting requires the use of a gun outside of one's home, which may increase the probability of detection.

1.6.3 Effects on Alcohol and Narcotic Crimes

Opening season is a significant addition to an individual's leisure opportunities, suggesting that individuals may substitute away from riskier leisure behavior that is more alcohol or narcotic related. As deer are most active at dawn and dusk, hunters go to sleep early and wake early, increasing the costs of binge drinking. Though ramifications vary by state, hunting under the influence is typically a misdemeanor crime resulting in jail time and a fine. Though a stereotype exists, hunting forums imply that hunting under the influence is rare while the Minnesota DNR reports zero to four citations per year for its 600,000 hunters.[9] Additionally, hunter-safety

[9] http://www.startribune.com/no-hunters-don-t-drink-and-hunt/459735393/

education courses, sportsman groups, and state guidebooks vilify drinking and hunting.[10] Results in Table 1.6 provide strong evidence that alcohol-related arrests drop approximately 8% the first two days of season. Similarly, narcotic offenses decrease 12% the first two days of season with estimates suggesting that effects dissipating after four days.

A potential concern is that law enforcement effort may change during firearm season. If enforcement decreases, then alcohol-related arrests and narcotic offenses should decrease for all demographics. Separate analysis of rural males 21 and under versus 40 and over in Figures 1.11b and 1.11a provide no evidence that alcohol-related arrests decrease for males 40 and over. Decreases in alcohol-related arrests are driven by young rural males. There is a 22% decrease in young rural male alcohol-related arrests on the opening day of firearm season, with similar reductions the day before and day after opening. The finding that young males are driving the decrease in alcohol-related arrests is consistent with recreational hunting incapacitating and deconcentrating young males, which are important factors of alcohol consumption.

It could be helpful to study what types of arrests are driving the decrease in young rural male alcohol-related arrests. If "idle hands are the devil's workshop" (Jacob and Lefgren, 2003), what are busy young males doing less of? Average zone-day arrests in Figures 1.A7a-1.A7d show that young male alcohol-related arrests are predominantly composed of arrests for DUI and liquor law violations. Results in Figure 1.A7a imply that young male DUI arrests are 22% lower on the opening day of firearm season. Similarly, estimates in Figure 1.A7b imply that young rural male liquor law violations decrease 20% the day before, day-of, and day after firearm season, implying that firearm season may decrease underage drinking arrests.

What demographic is driving the decrease in narcotic offenses? Figures 1.12a and 1.12b report estimates separately for males 21 and under and 40 and over. Estimates in Figure 1.12a provide clear evidence that young male narcotic offenses exhibit a significant drop (approximately 10-15%) that lasts up to ten days after firearm season opens. For males 40 and over, there is evidence of drops in narcotic offenses the first two days of firearm season, but these effects are not persistent.

[10]https://www.hunter-ed.com/wisconsin/studyGuide/Alcohol-and-Drugs/20205101_700174149/

Once again, there is a concern that decreases in law enforcement could explain these results. Notably, estimates for young rural males suggest that firearm season decreases narcotic offenses for the first four days of firearm season, with the strongest decrease on opening day.

In aggregate, results provide strong evidence that firearm season reduces alcohol- related arrests for young rural males. It is my hypothesis that reductions in alcohol-related arrests should be driven by hunting zones that open season on days when typical leisure activities are most likely to include alcohol: the weekend. Table 1.A3 provides strong evidence that young male alcohol-related arrests decrease in hunting zones that open on a weekend. Results suggest that alcohol-related arrests are 18% lower the first two days of firearm season. For hunting zones that open on a weekday, estimates are negative but precision varies by specification. This suggests that the recreational opportunities of firearm season may have the benefit of reducing alcohol-related arrests, but only if the season starts on a weekend.

1.6.4 Robustness to Law Enforcement Agency Population

The baseline model aggregates all criminal incidents in a rural zone-day cell, where rural is defined as a law enforcement agency covering less than 25,000 individuals. A natural concern is that results could be sensitive to the definition of rural. Previous figures and results show that the largest increases in hunting activity and gun prevalence occur on the first two days of firearm season. Therefore, I iteratively estimate specification 1.1, with event-time leads and lags but bunching the first two days of season, for various agency population ranges. As hunting is more prominent in rural areas, we should generally expect increases in gun prevalence to be larger for law enforcement agencies covering smaller populations.

True to form, estimates in Figure 1.13 illustrate that long gun prevalence is 530% higher on the first two days of firearm season for agencies covering less than 1,000 individuals. Remarkably, overlaid estimates suggest that there are approximately 12% fewer violent crime incidents on the first two days of firearm season for these less populated agencies. Corresponding estimates for agencies covering populations over 1,000 and less than 50,000 indicate that long gun prevalence is approximately 50%-125% higher, while all estimated effects on violent crime incidents consistently hover around zero. Estimated effects on long gun prevalence disappear for agencies covering more than 50,000 individuals, which aligns with lower hunting participation in urban areas.

Similarly, Figure 1.14 breaks out estimated effects on alcohol-related arrests by age group of the offender and population of the law enforcement agency. Estimates suggest that decreases in alcohol-related arrests are greatest for less populous areas and for younger males. Males under the age of 18 exhibit 24%-38% decreases in alcohol-related arrests on the first two days of firearm season for agencies covering less than 15,000 individuals. Meanwhile, males 40 and over only exhibit decreases in alcohol-related arrests for agencies covering less than 1,000 individuals.

1.7 Discussion

The results of this paper provide strong evidence that enormous increases in recreational long gun prevalence are *not* associated with *any* increase in violent crime. In the least populous areas, where long gun prevalence increased 530%, estimates suggest that male violent crime actually decreased. This section discusses three reasons why my results might differ from the aggregate positive relationship between guns and crime often found in previous studies.

First, hunting is a time-consuming activity that is inherently incapacitating, which may decrease crime (Jacob and Lefgren, 2003; Dahl and DellaVigna, 2009). Various sources of deer hunter data suggest that hunters spend upwards of six hours per day in the field, with additional time spent processing harvested deer. Males may be too preoccupied to use their guns nefarious purposes. Additionally, hunting may decrease social interaction (due to hunting in the woods) which may decrease potential violent conflict (Jacob and Lefgren, 2003).

Second, hunters may comprise a low-risk sample. As stated in Cook et al. (2010), hunters are often older white males in rural areas while violent crime is more rampant among young minority males in urban areas. However, casting all hunters as old white males ignores the large contingent of young male hunters (Figures 1.A1a-1.A1b). No demographic has been more vilified concerning gun use and crime than young males. Why isn't gun use among young rural male hunters associated with an increase in violent crime?

One potential reason is that the context in which a young rural male acquires a gun differs from the context of a young urban male, who are often highlighted in the literature. Historically, hunting has primarily been a tradition passed down from father to son. To the degree that young hunters adopt behavior similar to low-risk role models like fathers (Case and Katz, 1991) and hunter education instructors, the peer effects that young hunters pick up regarding guns will differ from that of youths in urban areas.

Another reason that hunters may be a low-risk sample is because patient individuals may select into deer hunting. Deer hunting is often characterized as an activity in which an individual sits in a tree stand for hours on end, waiting for a deer to walk by. It is possible that only patient individuals are willing to participate in this gun-related recreational activity. Lochner and Moretti (2004) cite increased patience as a mechanism that decreases propensity to commit crime because more patient people discount future punishments less.

Third, hunters may face more regulation than other gun owners. These regulations may improve firearm etiquette *and* discourage high-risk individuals from hunting. In a 2015 survey, Rowhani-Rahbar et al. (2018) estimate that only 61% of firearm owners have received firearm training. To the contrary, all hunters must pass a hunter education course (unless grandfathered out) that teaches proper firearm use and etiquette. Therefore, all non-grandfathered hunters have received formal firearm training while many non-hunters haven't. After passing a hunter education course, an individual must purchase a hunting license and deer tag for each deer they desire to harvest. Although no background check is required, formal paperwork and courses that require placing one's name in a state database may discourage individuals who illegally possess a firearm from hunting. This is particularly important as individuals who commit gun crimes often do not legally possess the firearm (Fabio et al., 2016).

1.8 Conclusion

This paper breaks new ground in gun policy research on a culturally iconic sample of gun owners that has before now gone unexplored: the 18% ($\approx$ 25% at the beginning of my sample) of American gun owners who use firearms to hunt. Each year, hunters expend approximately 30% of all shots fired in America. This paper tests the contentious claim of rural long gun owners that their firearm use does not increase violent crime. I am the first to examine how irregularities in hunting season regulations, which increase long gun use over 300%, impact violent crime in rural America. To my knowledge, this is the first quasi-experimental study, with direct estimates of actual firearm use, that examines the effects of firearm use on violent crime. The enormous changes in firearm use caused by hunting regulations are unparalleled by any other policy in existence. There are no other policies that induce 600,000 Wisconsin males or 530,000 Michigan males to systematically and temporarily carry and use firearms.

Despite the fact that firearm season increases rural long gun use by over 300%, estimates using within-hunting zone variation provide no evidence that rural violent crime increases. I estimate the elasticity of violent crime with respect to recreational long gun use to be between -0.01 and +0.0003. While there is no evidence of an increase in violent crime, results suggest that male weapon law violations increase substantially. Americans exude dichotomous perspectives concerning the relationship between gun use and violent crime. Paradoxically, both perspectives may be correct if the patterns between gun use and violent crime are heterogeneous across gun users and gun types. My results suggest that previous studies examining the violent crime effects of aggregate gun ownership or use may muddy the detrimental effects of urban-skewed handguns with the nonexistent effects of rural-skewed long guns. Stark differences in gun types and reasons for ownership between urban and rural individuals may be one mechanism by which guns have a stronger link to violent crime in urban areas.

Firearm deer hunting is a recreational activity that rural males strongly anticipate. Additional recreation opportunities like firearm hunting could partially offset the negative externality of alcohol and drug consumption if males substitute away from riskier behavior and toward hunting. I find strong evidence that alcohol-related arrests of juvenile males fall by 22% and narcotic offenses fall by 15% at the start of hunting season. Aligning with juvenile alcohol consumption patterns, my results suggest that hunting zones that open season on a weekend may experience larger decreases in alcohol-related crime.

One limitation of this study is lack of daily injury and mortality data. While the effects of gun use and violent crime are a hot area of debate, the enormous increase in gun use and access during firearm deer season could exert social costs not captured by violent crime. Child-access prevention (CAP) laws have been found to decrease suicides and unintentional injuries or death (Morral et al., 2018). While handguns are a more common implement for suicide, individuals may substitute to long guns if relative ease of access changes. As long gun access unequivocally increases during firearm season, for hunters and non-hunters, future work should examine the link between increased long gun use and non-crime related costs.

Table 1.1: Hunting Summary Statistics

Hunters	**13.7 million**
Male	12.2 million
Female	1.5 million
Big Game	11.6 million
Deer	10.9 million
Wild Turkey	3.1 million
Elk	0.9 million
Bear	0.5 million
Small Game	4.5 million
Migratory Birds	2.6 million
Other Animals	2.2 million
Days	**282 million**
Big Game	212 million
Small Game	51 million
Migratory Birds	23 million
Other Animals	34 million
Expenditures	**$33.7 billion**
Big Game	16.9 billion
Small Game	2.6 billion
Migratory Birds	1.8 billion
Other Animals	0.9 billion
Nonspecific	11.9 billion
Equipment Expenditures	**$7.38 billion**
Firearms	3.05 billion
Rifles	1.43 billion
Shotguns	0.91 billion
Muzzleloaders/primitive	0.12 billion
Pistols/handguns	0.58 billion
Ammunition	1.29 billion

Notes: Data from 2011 FHWAR. Hunters by game-type do not sum to total hunters because hunters often hunt multiple types of game (deer and small game, for example). Examples of small game include rabbits and squirrels.

Table 1.2: Summary Statistics of Hunting Demographics

Percent of US Hunters by Race	
White	94%
African American	3%
Asian American	.5%
Other	3%
Percent of Poulation who Hunted by Poulation	
Large MSA (1 Million+)	3%
Medium MSA (250K-1 Million)	5%
Small MSA (50K-250K)	11%
Outside MSA	18%
Percent of Hunters by Location of Hunt	
In-state	86%
In & Out-of-State	8%
Out-of-state only	6%
Number of Hunters by Weapon	
Rifle, Shotgun, etc.	12.73 million
Bow	4.472 million
Muzzleloader	2.981 million
Hunters by Type of Land	
Private Only	8.4 million
Public & Prviate	3.2 million
Public Only	1.7 million
Undetermined	0.4 million

Notes: Data from 2011 FHWAR. Hunters by weapon do not sum to total hunters because hunters may use multiple weapons. Tables 1.1-1.2 suggest that hunters are predominantly white rural males.

Table 1.3: Firearm Ownership Rates by Demographic

Demographic	**Any Firearm**	**Handgun Only**	**Long Gun Only**	**Both**
All Respondents	22	6	5	11
Sex				
Male	32	7	8	18
Female	12	5	2	5
Race				
White	25	5	6	13
Hispanic	16	6	3	7
Black	14	8	1	5
Community				
Urban	15	6	3	7
Suburban	19	6	4	10
Rural	33	5	9	19

Notes: Males, white individuals, and rural individuals all have above average firearm ownership rates. This table implies that rural white males have high firearm ownership rates, especially ownership of long guns. Table from Azrael et al. (2017); 2015 National Firearms Survey

Table 1.4: Reasons for Ownership by Firearm Type

	Protection from			
Gun Type	**People**	**Animals**	**Hunting**	**Other Sporting Use**
Handgun only, 1	0.78	0.10	0.03	0.00
Handgun only, >1	0.83	0.12	0.01	0.00
Long gun only, 1	0.36	0.14	0.46	0.17
Long gun only, > 1	0.27	0.20	0.65	0.41
Handgun & long gun	0.72	0.27	0.55	0.47

Notes: Long gun owners are significantly more likely to own a firearm for hunting, protection from animals, or other sporting uses. Table modified from Azrael et al. (2017); 2015 National Firearms Survey.

Table 1.5: Estimated Effects of Firearm Season on Male Rural Crime

	(1)	(2)	(3)
Armed Arrestees (Long)			
3-5 Days Before	0.559	0.666**	0.272**
	(0.354)	(0.313)	(0.135)
1-2 Days Before	0.803*	0.829***	0.360***
	(0.432)	(0.239)	(0.0792)
Opening 2 Days	1.351***	1.465***	1.359***
	(0.289)	(0.244)	(0.229)
3-4 Days After	0.692**	0.563**	0.457***
	(0.306)	(0.245)	(0.168)
5-7 Days After	0.465***	0.547***	0.398***
	(0.0774)	(0.118)	(0.124)
Observations	136,615	122,763	88,536
Violent Crime Offenses			
3-5 Days Before	-0.0268	-0.00819	-0.0187
	(0.0258)	(0.0329)	(0.0315)
1-2 Days Before	0.00636	0.0117	0.00364
	(0.0210)	(0.0243)	(0.0238)
Opening 2 Days	0.00115	0.00562	-0.00110
	(0.0197)	(0.0230)	(0.0290)
3-4 Days After	-0.000431	-0.00937	-0.0177
	(0.0227)	(0.0271)	(0.0245)
5-7 Days After	0.0109	0.0232	0.0100
	(0.0180)	(0.0181)	(0.0121)
Observations	135,969	135,604	128,998
Zones	29	29	29
Day-of-Week FE	Yes	No	No
Week-of-Year FE	Yes	No	No
Year FE	Yes	No	No
Day-of-Panel FE	No	Yes	Yes
Zone FE	No	Yes	No
Zone-by-Month FE	No	No	Yes

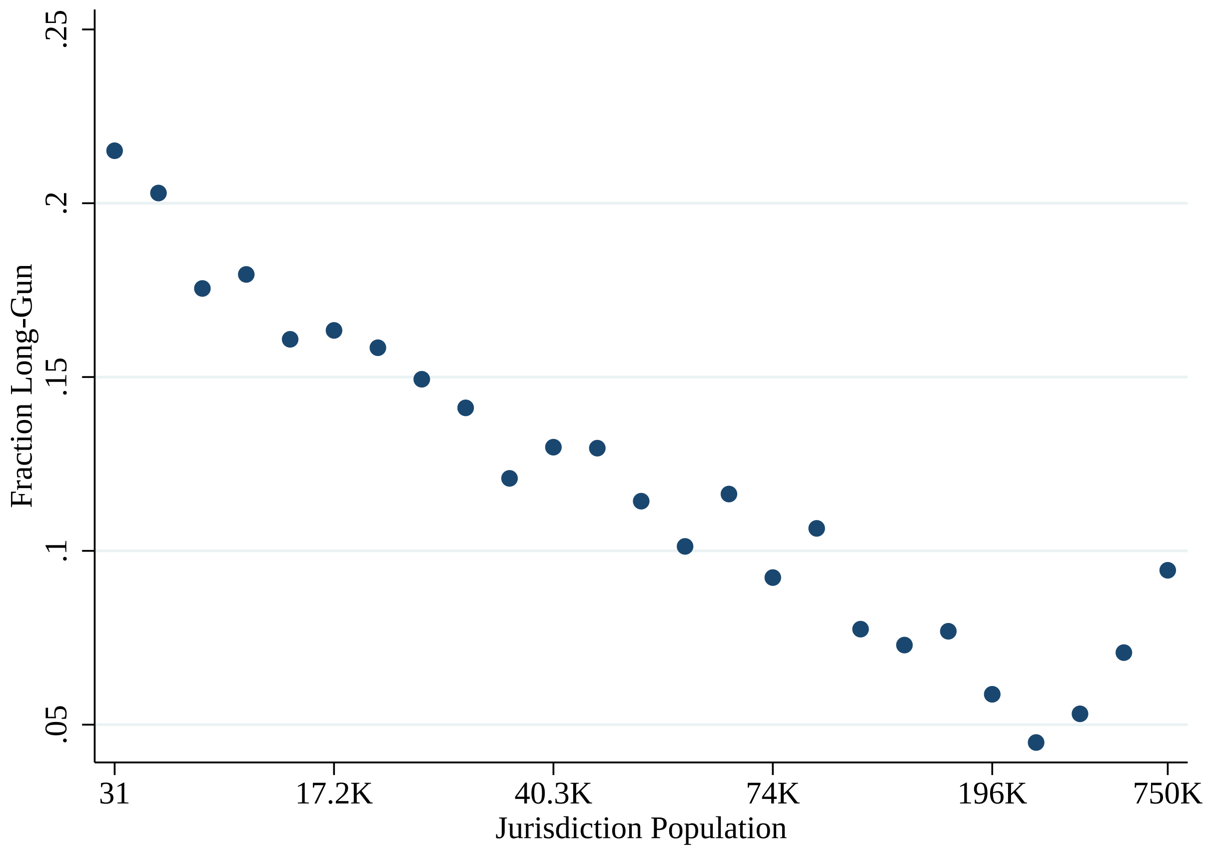
Notes: The dependent variable is a zone-day count of crime. Armed Arrestees (Long) denote the number of arrestees who were armed with a long gun upon arrest. This denotes gun prevalence, as individuals arrested for nonviolent reasons (like DUI) may be armed. Violent crime offenses are an aggregation of reported aggravated assault, murder, rape, and robbery. Standard errors clustered at the zone level. Poisson estimates are reported, implying that percent effects are $(e^{\beta}-1)$ x 100%. Observation counts vary across specifications because observations in fixed effects Poisson models are dropped if the outcome does not vary within a fixed effect group. *** p<0.01, ** p<0.05, * p<0.1

Table 1.6: Estimated Effects of Firearm Season on Male Rural Crime

	(1)	(2)	(3)
Alcohol-Related Arrests			
3-5 Days Before	0.0211	0.0223	0.0421
	(0.0525)	(0.0330)	(0.0296)
1-2 Days Before	-0.0128	0.0105	0.0275
	(0.0249)	(0.0387)	(0.0311)
Opening 2 Days	-0.0922***	-0.0932***	-0.0776***
	(0.0212)	(0.0222)	(0.0174)
3-4 Days After	-0.0239	-0.0238	-0.00143
	(0.0188)	(0.0204)	(0.0219)
5-7 Days After	-0.0315	-0.0399**	-0.0203
	(0.0218)	(0.0202)	(0.0144)
Observations	136,615	136,250	131,715
Narcotic Offenses			
3-5 Days Before	-0.0346	0.0129	0.0192
	(0.0215)	(0.0268)	(0.0270)
1-2 Days Before	0.0112	0.0101	0.0192
	(0.0259)	(0.0321)	(0.0329)
Opening 2 Days	-0.112***	-0.119***	-0.114***
	(0.0278)	(0.0262)	(0.0283)
3-4 Days After	-0.0328	-0.0505**	-0.0445*
	(0.0282)	(0.0256)	(0.0270)
5-7 Days After	-0.0176	-0.00910	-0.00537
	(0.0215)	(0.0224)	(0.0237)
Observations	135,969	135,604	129,803
Zones	29	29	29
Day-of-Week FE	Yes	No	No
Week-of-Year FE	Yes	No	No
Year FE	Yes	No	No
Day-of-Panel FE	No	Yes	Yes
Zone FE	No	Yes	No
Zone-by-Month FE	No	No	Yes

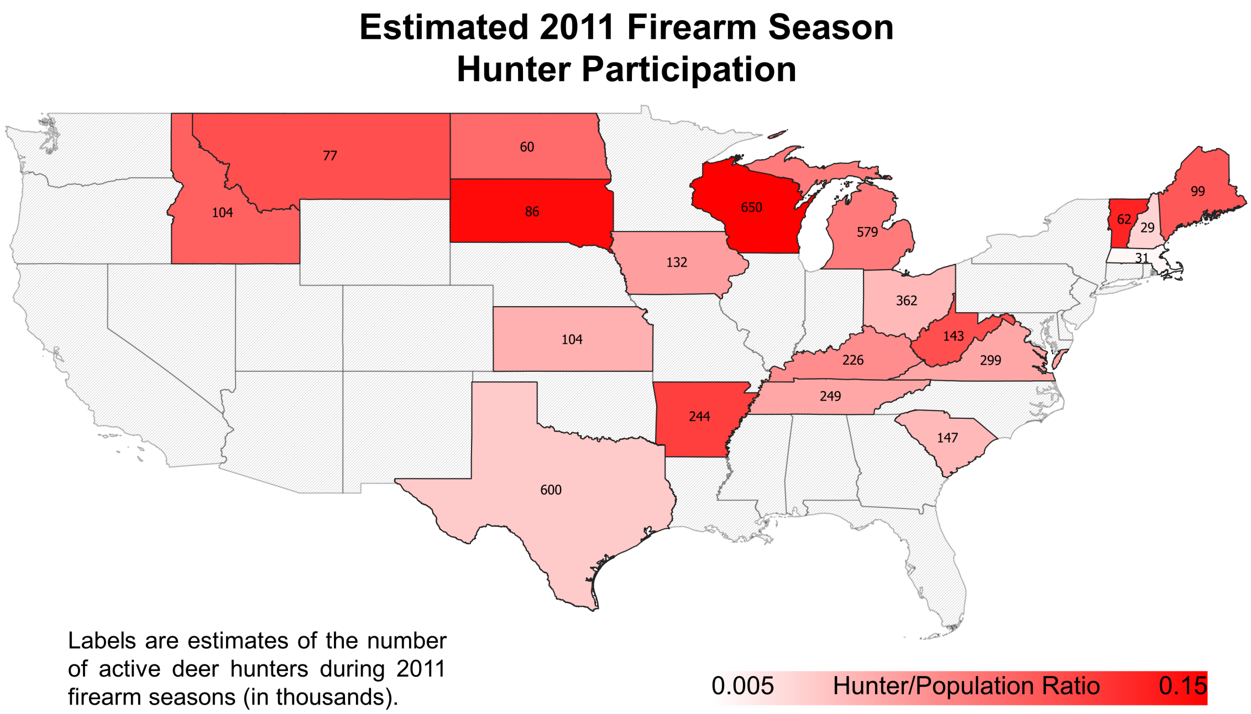
Notes: Alcohol-related arrests include arrests for driving under the influence (DUI), liquor law violations, disorderly conduct, and drunkenness. Narcotic offenses include possession, consumption, manufacture, or dealing of illicit drugs. Standard errors clustered at the zone level. Poisson estimates are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. *** p<0.01, ** p<0.05, * p<0.1

Figure 1.1: Long Gun Use in Violent Crime Offenses



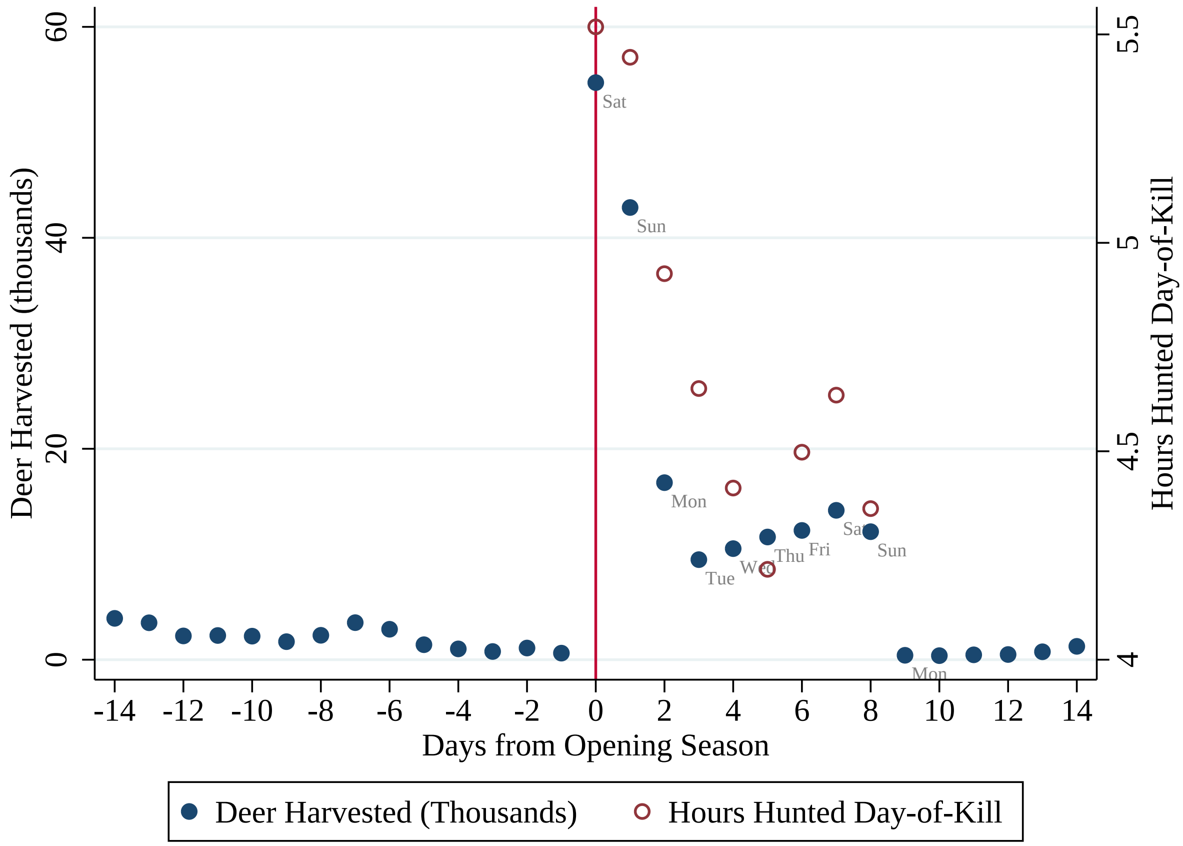
Notes: This figure reveals that long guns are used in violent crimes, particularly in rural areas. The calculation is limited to violent crime (VC) offenses where the firearm type is identified and is calculated as $\frac{VC_{Long\ Gun}}{VC_{Long\ Gun}+VC_{Handgun}}$. Data are from NIBRS sample 1995-2015.

Figure 1.2: 2011: Estimated Participation in Main Firearm Season for States Covered by NIBRS



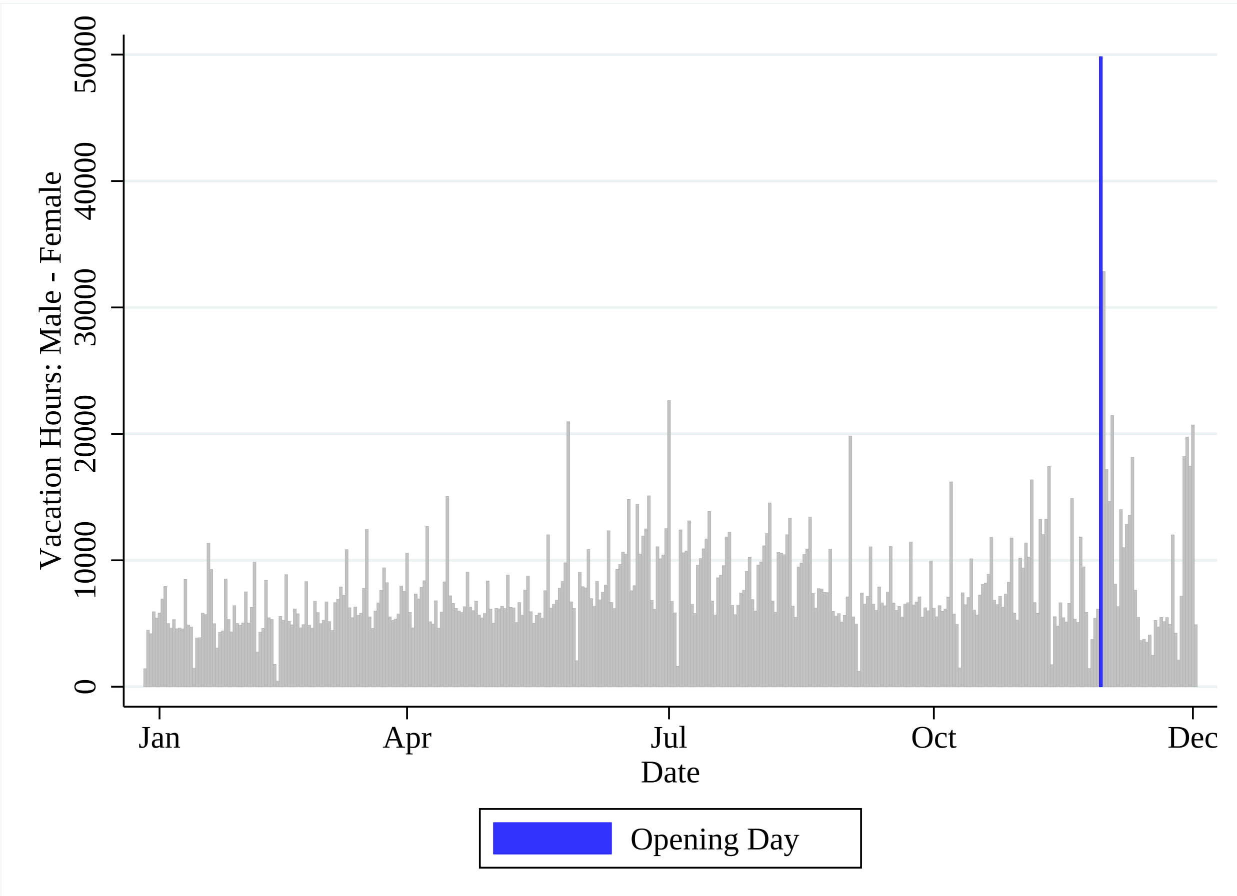
Notes: Data do not cover all states because NIBRS coverage is not complete. Firearm season estimates are directly from state agencies or estimated using 2011 US Fish, Hunting, and Wildlife-Associated Recreation (FHWAR) as 3/4 of the state's firearm deer hunters.

Figure 1.3: Patterns of Hunting Around Wisconsin Opening Day (2017)



Notes: Data are from Wisconsin Department of Natural Resources (DNR). The Wisconsin DNR estimates that over 600,000 hunters were active throughout the 9-day season. Total active hunters $= \frac{\text{Daily Deer Harvest}}{\text{Daily Success Rate}}$. While daily success rates do not exist, DNR survey data estimated the overall 2017 success rate to be 34%. The daily success rate is lower, as firearm hunters averaged 4.3 days of hunting. The hollow red circles show that successful hunters averaged over 5 hours in the field on the first two days of season.

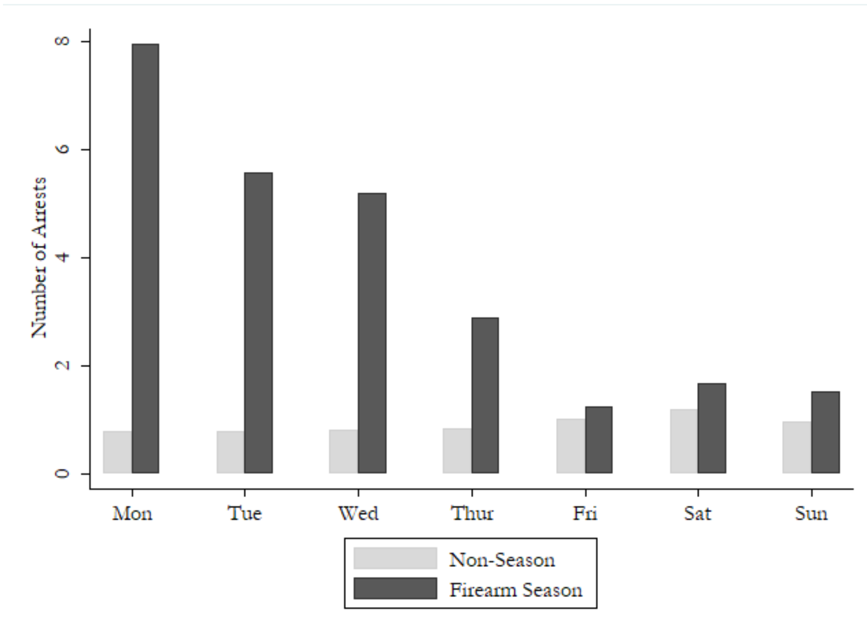
Figure 1.4: Pennsylvania Employee Male-Female Vacation Hour Differential (2016)



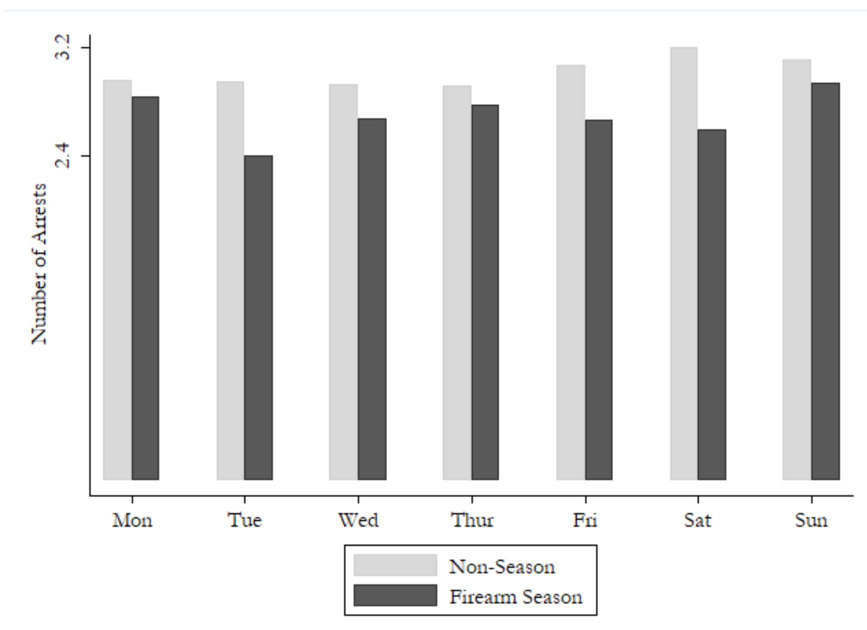
Notes: Data are from a FOIA request of all state leave for employees working for Pennsylvania state agencies. The data cover over 2.2 million documentations of employee leave, split by type: annual-vacation or sick leave. On average male state employees take 3,826 more vacation hours per day than females. On opening day of firearm season, they take 50,000 more vacation hours than females.

Figure 1.5: Rural Male Arrests in Zones Opening on Monday

(a) Number of Armed Arrestees

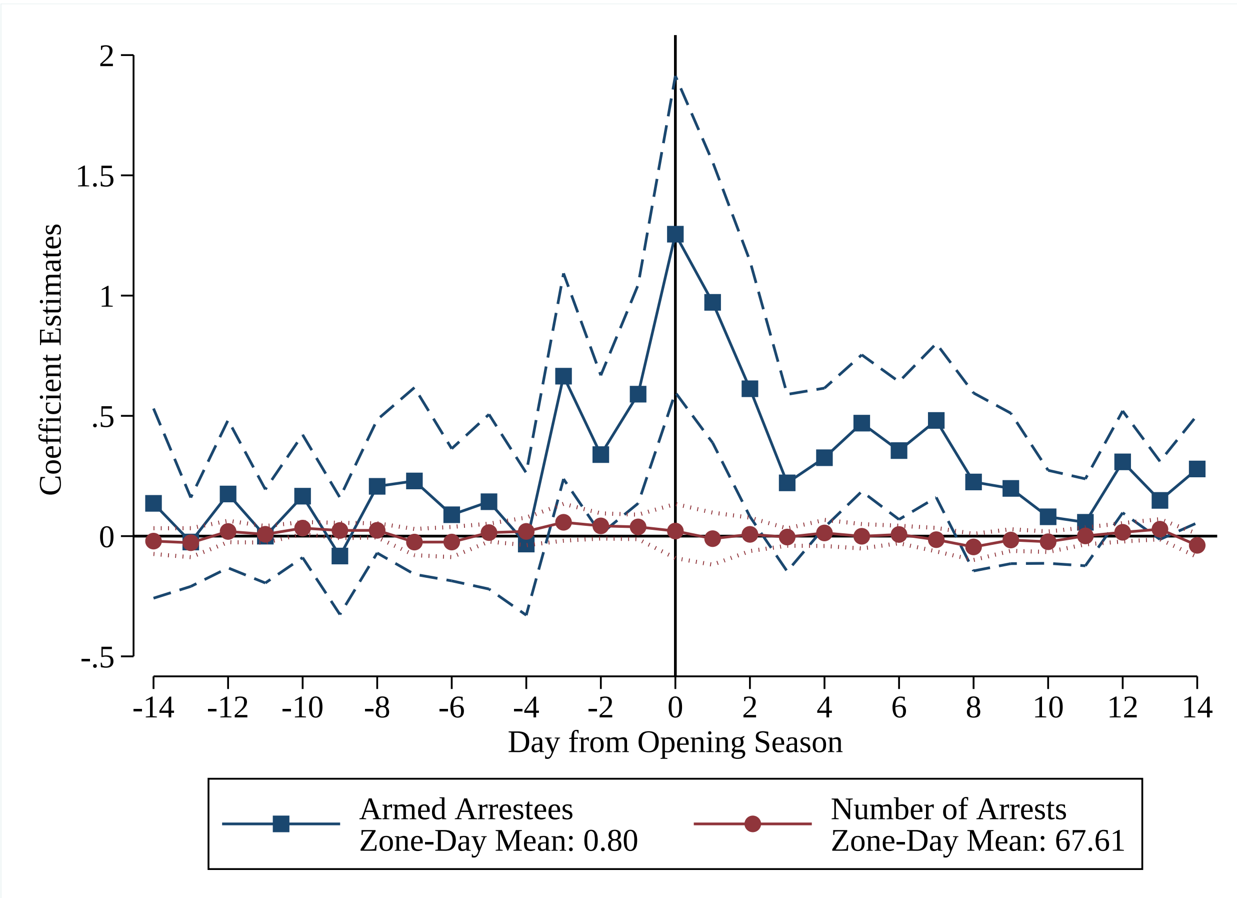


(b) Number of Violent Crime Arrests



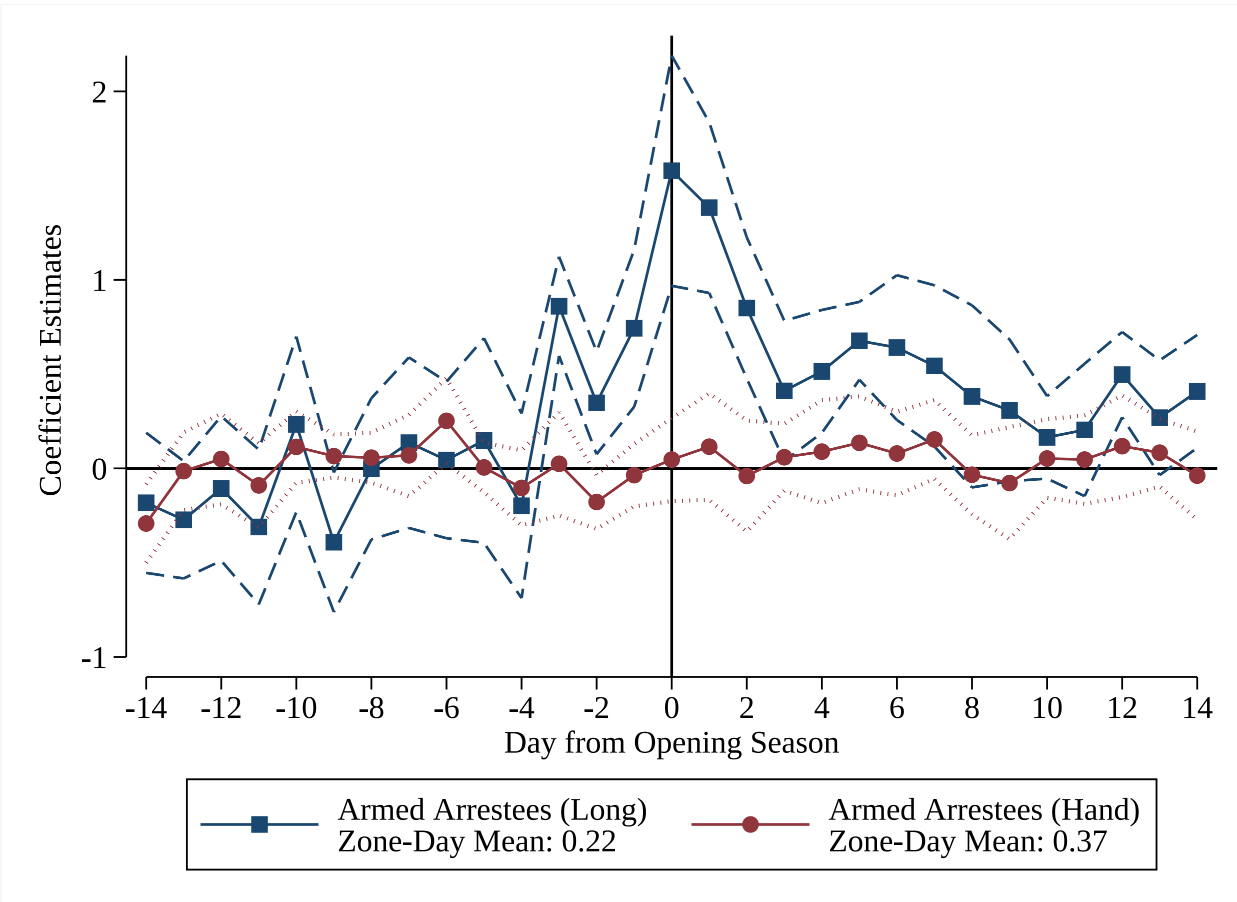
Notes: This figure displays average daily male armed arrestees and violent crime (aggravated assault, murder, rape, and robbery) arrests for zones that open on Monday. Averages are provided for the opening week of firearm season and for other weeks of the year.

Figure 1.6: Estimated Effects of Firearm Season on Rural Male Gun Prevalence and Number of Arrests Using Variation in Season Access



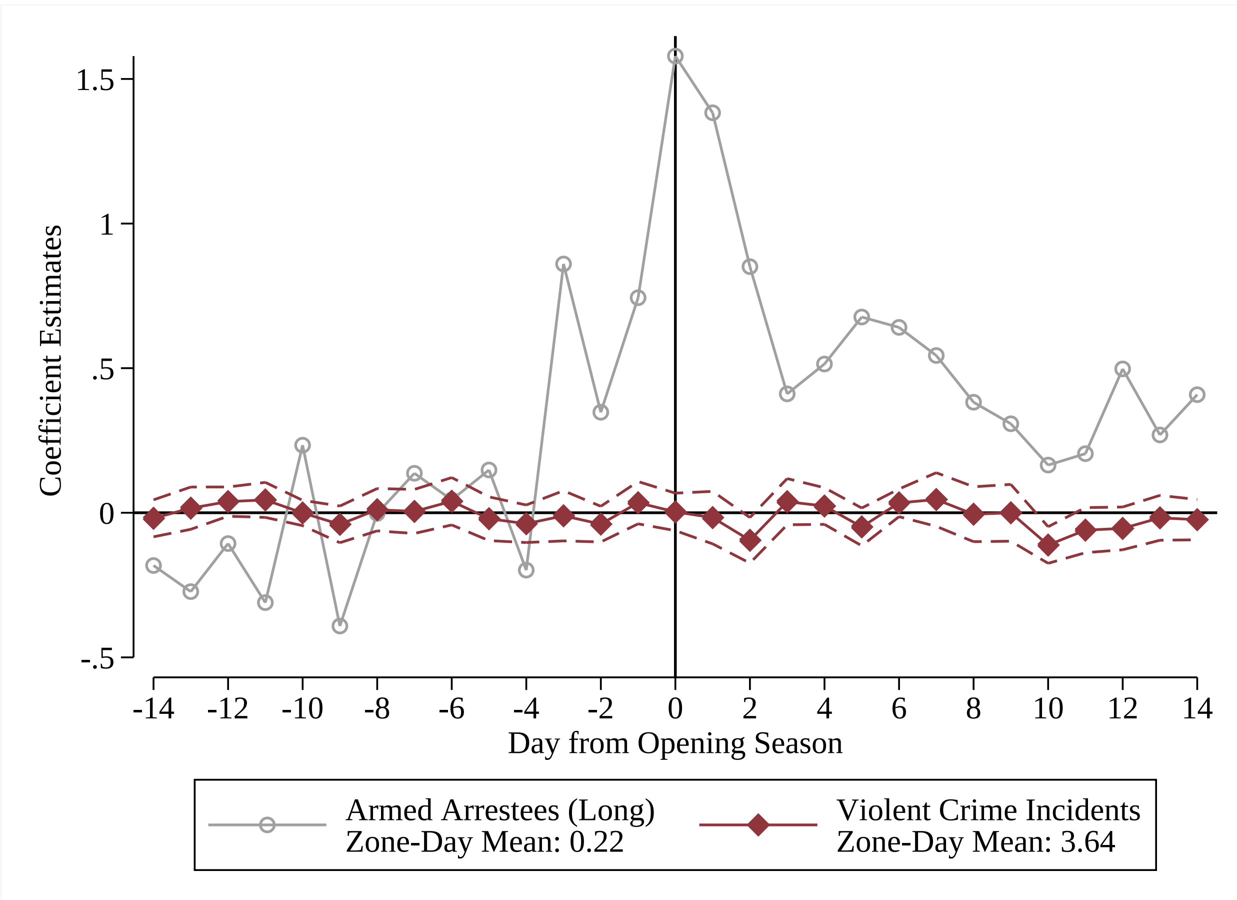
Notes: Violent crime offenses are an aggregation of reported aggravated assault, murder, rape, and robbery. The mean of the dependent variable is the average count of respective arrests per zone-day. Poisson estimates of leads and lags are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. The model includes day-of-panel and zone-month fixed effects. Standard errors are clustered by zone, with 95% confidence intervals provided.

Figure 1.7: Estimated Effects on Rural Male Armed Arrestees with Handguns versus Long Guns to Test Attribution



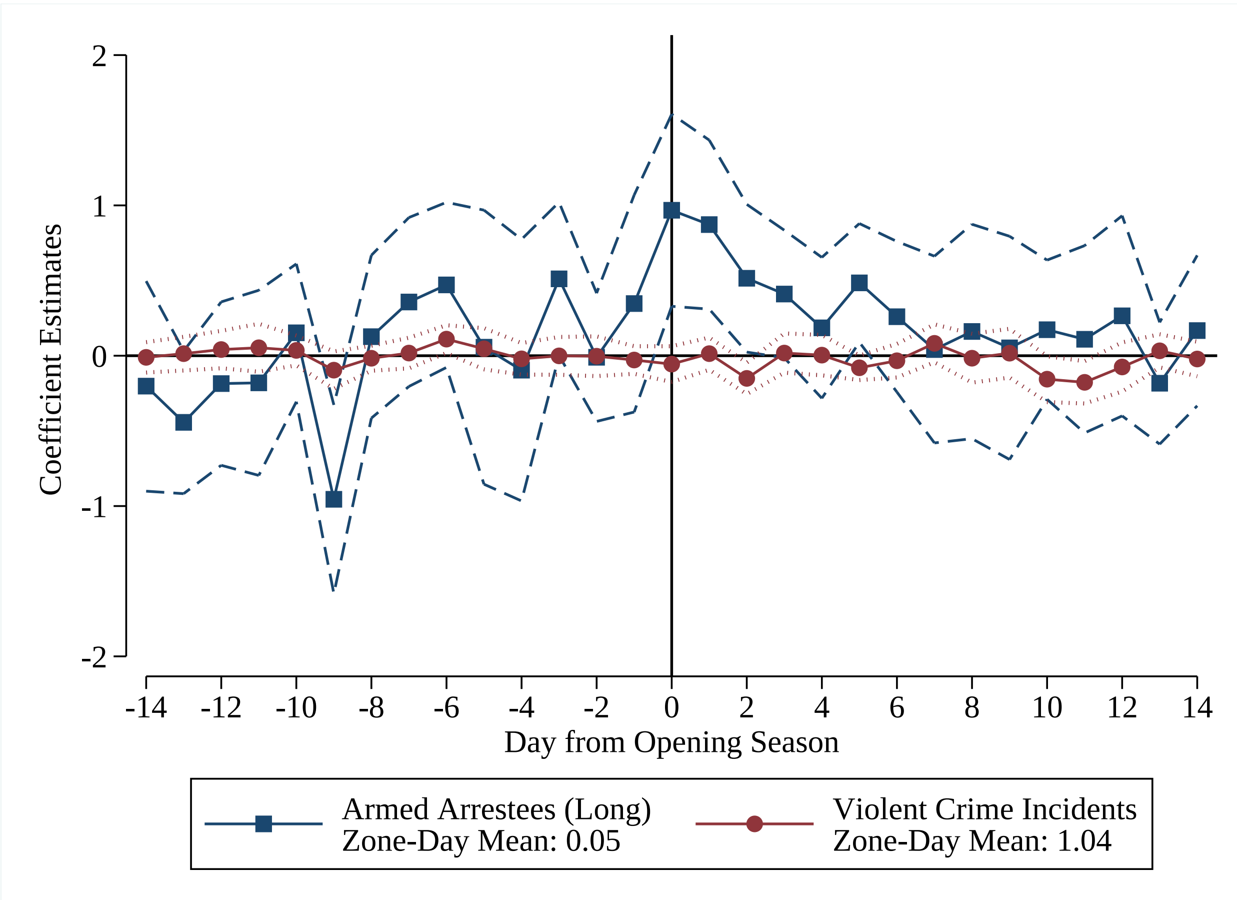
Notes: This figure shows that increased gun prevalence is driven purely by long guns, suggesting the design is not picking up effects driven by other factors that influence gun prevalence. The mean of the dependent variable is the average count of respective arrests per zone-day. Poisson estimates of leads and lags are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. The model includes day-of-panel and zone-month fixed effects. Standard errors are clustered by zone, with 95% confidence intervals provided.

Figure 1.8: Estimated Effects of Firearm Season on Rural Male Long Gun Prevalence and Violent Crime Incidents



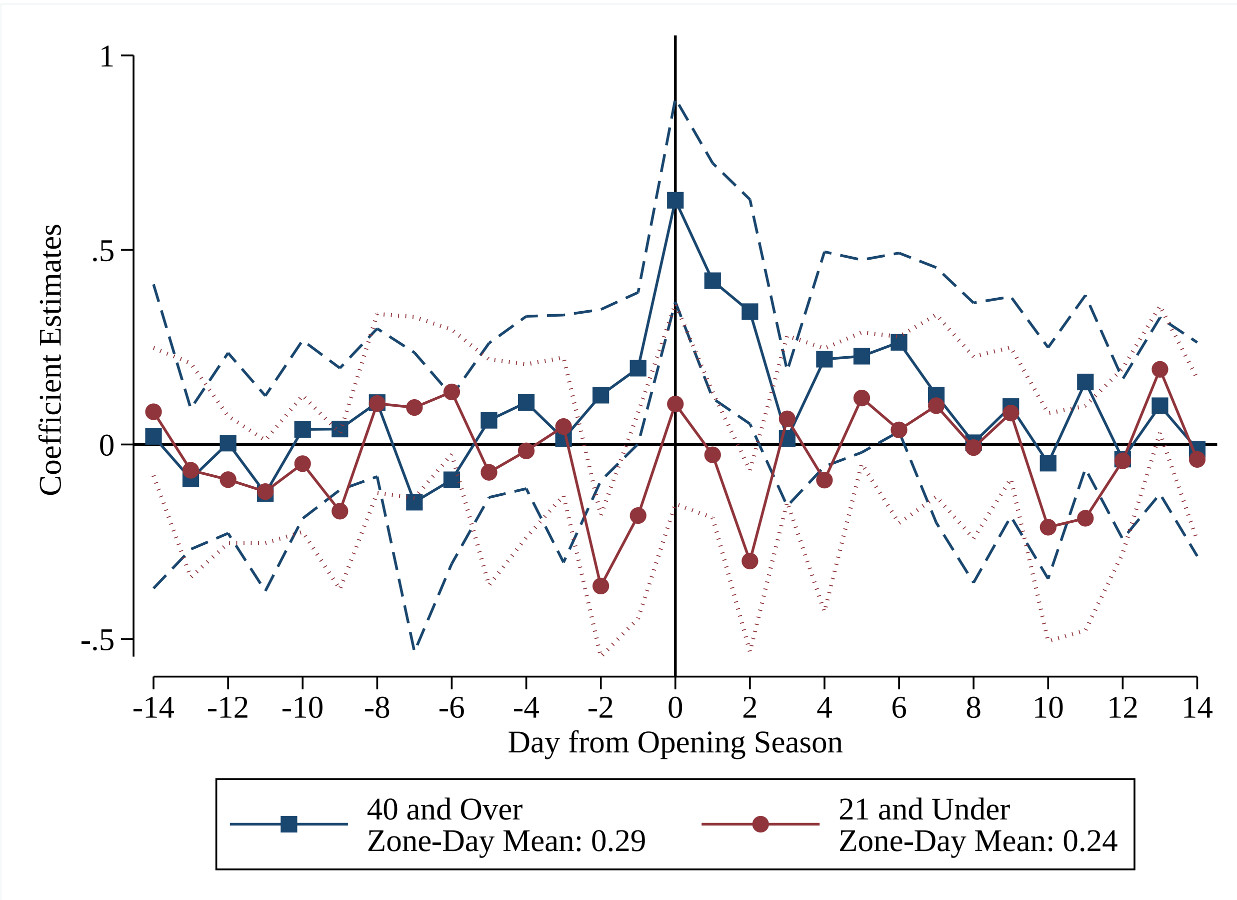
Notes: Violent crime incidents are an aggregation of reported aggravated assault, murder, rape, and robbery. The mean of the dependent variable is the average count of respective arrests per zone-day. Poisson estimates of leads and lags are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. The model includes day-of-panel and zone-month fixed effects. Standard errors are clustered by zone, with 95% confidence intervals provided.

Figure 1.9: Estimated Effects of Firearm Season on Young (21 & under) Rural Male Long Gun Prevalence and Violent Crime Incidents



Notes: Violent crime incidents are an aggregation of reported aggravated assault, murder, rape, and robbery. The mean of the dependent variable is the average count of respective arrests per zone-day. Poisson estimates of leads and lags are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. The model includes day-of-panel and zone-month fixed effects. Standard errors are clustered by zone, with 95% confidence intervals provided.

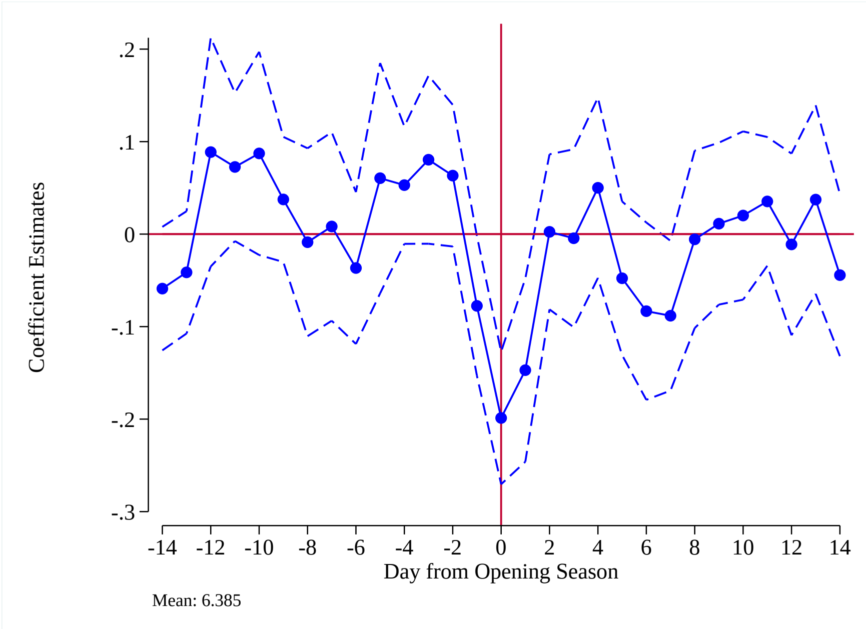
Figure 1.10: Estimated Effects of Firearm Season on Weapon Law Violations by Age



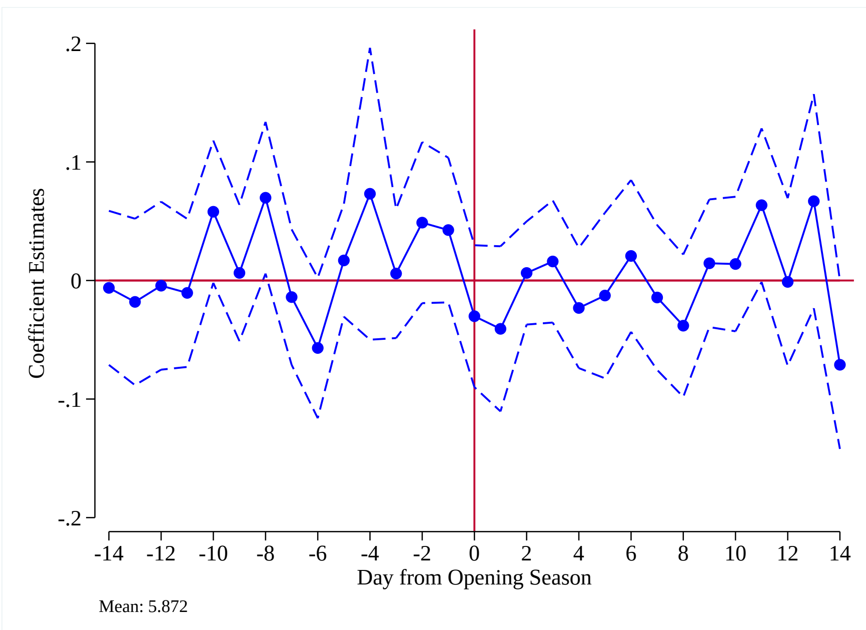
Notes: Weapon law violations include arrests for illegally carrying a concealed weapon, unlicensed weapon possession, unregistered weapon possession, using suppressors (silencers), et cetera. The mean of the dependent variable is the average count of respective arrests per zone-day. Poisson estimates of leads and lags are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. The model includes day-of-panel and zone-month fixed effects. Standard errors are clustered by zone, with 95% confidence intervals provided.

Figure 1.11: Estimated Effects of Firearm Season on Male Alcohol Arrests by Age

(a) Male 21 & Under



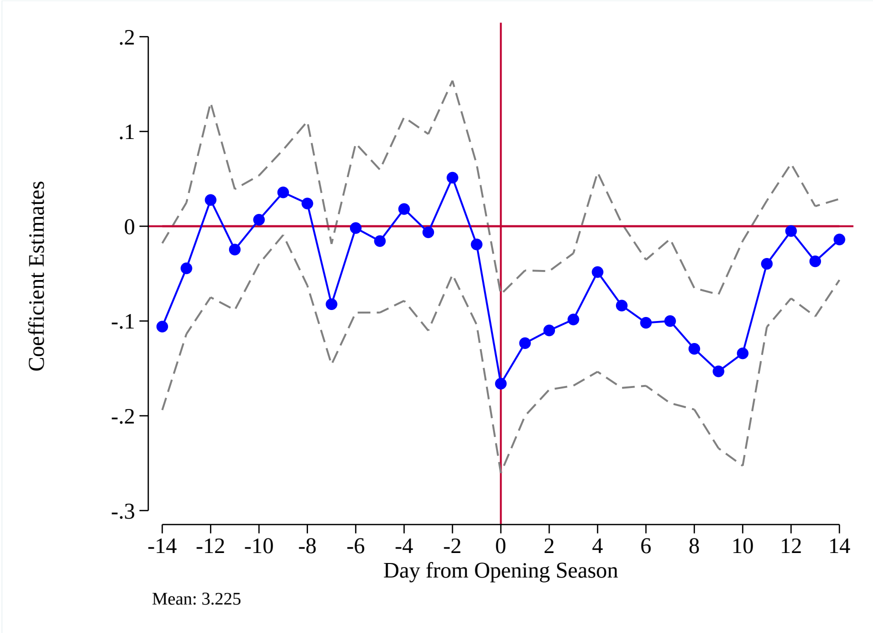
(b) Male 40 & Over



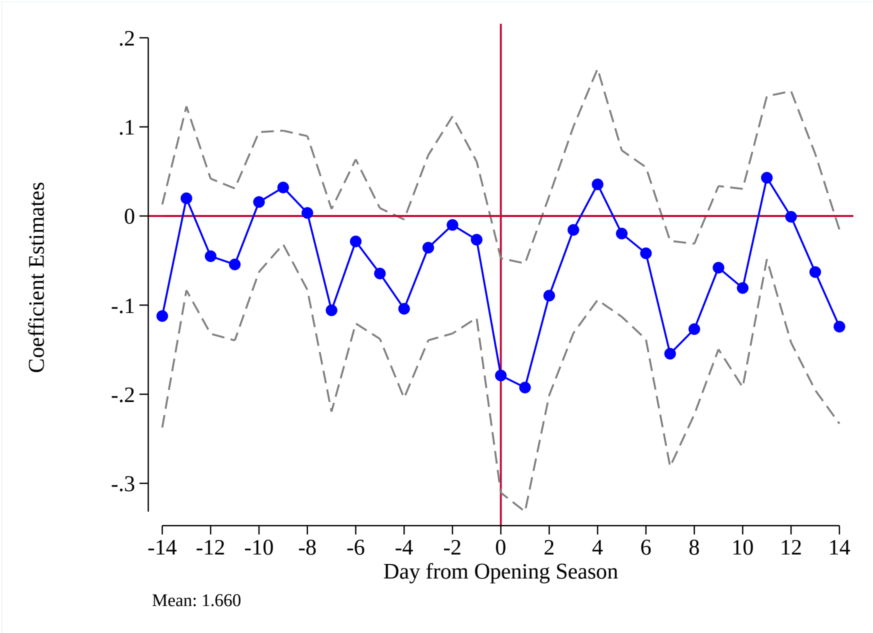
Notes: Alcohol-related arrests are an aggregation of arrests for driving under the influence (DUI), liquor law violations, disorderly conduct, and drunkenness. The mean of the dependent variable is the average count of respective arrests per zone-day. Poisson estimates of leads and lags are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. The model includes day-of-panel and zone-month fixed effects. Standard errors are clustered by zone, with 95% confidence intervals provided.

Figure 1.12: Estimated Effects of Firearm Season on Narcotic Offenses by Age

(a) Rural Males 21 & Under

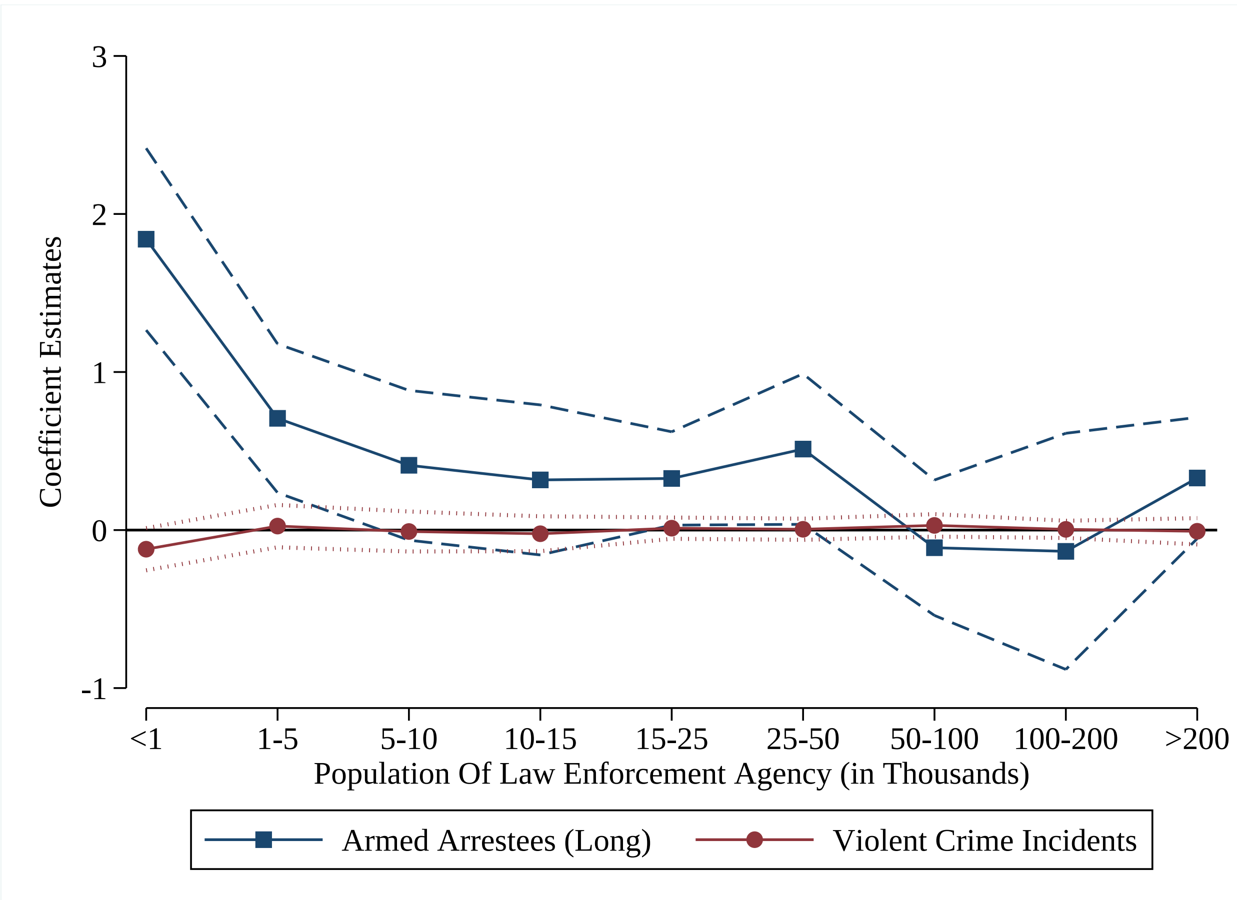


(b) Rural Males 40 & Over



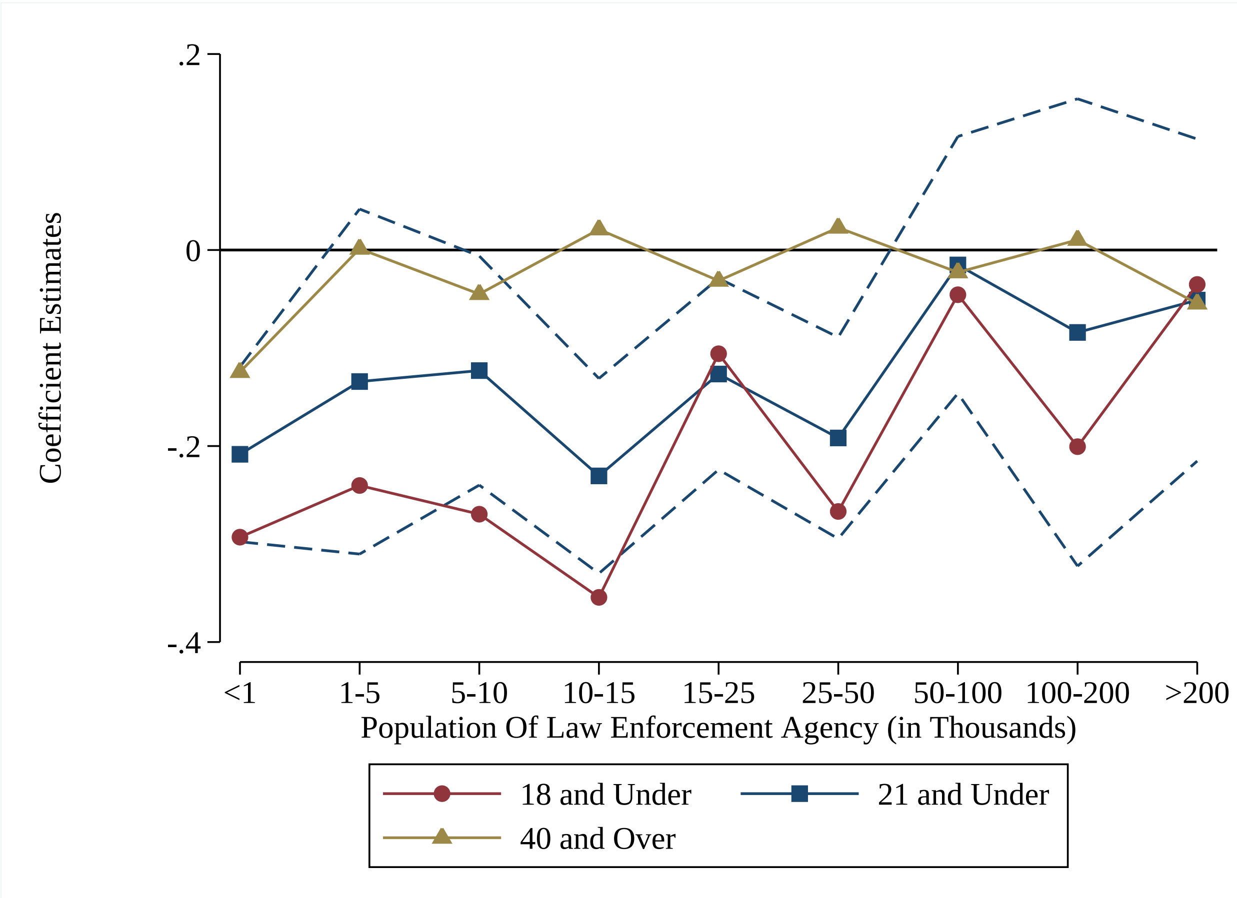
Notes: Narcotic offenses include possession, consumption, manufacture, or dealing of illicit drugs. The mean of the dependent variable is the average count of respective arrests per zone-day. Poisson estimates of leads and lags are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. The model includes day-of-panel and zone-month fixed effects. Standard errors are clustered by zone, with 95% confidence intervals provided.

Figure 1.13: Estimated Effects on Violent Crime Incidents on First Two Days of Season by Population of Law Enforcement Agency



Notes: Violent crime incidents are an aggregation of reported aggravated assault, murder, rape, and robbery. Poisson estimates are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. The model includes day-of-panel and zone-month fixed effects. Standard errors are clustered by zone, with 95% confidence intervals provided.

Figure 1.14: Estimated Effects on Alcohol-Related Arrests on First Two Days of Season by Population of Law Enforcement Agency

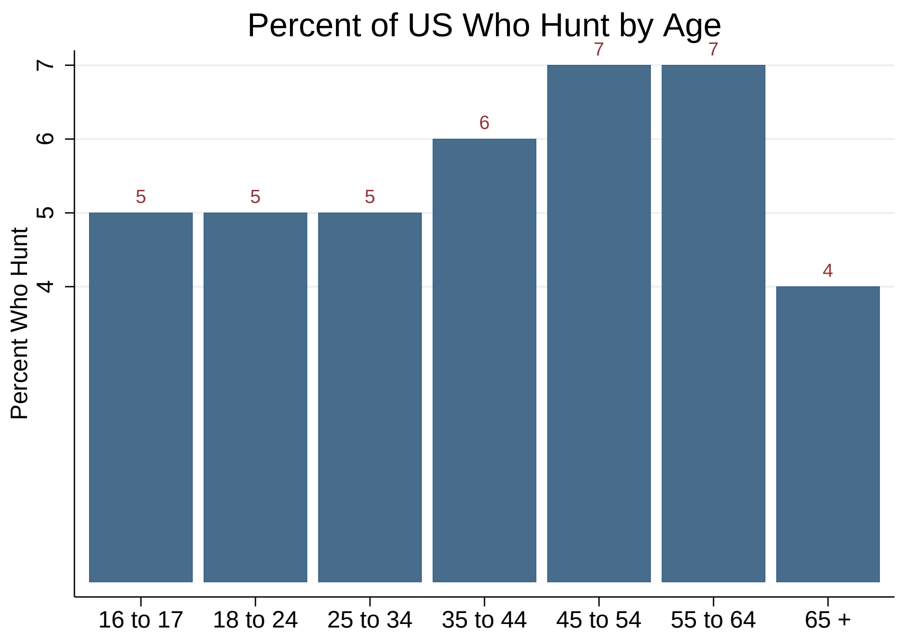


Notes: Alcohol-related arrests are an aggregation of arrests for driving under the influence (DUI), liquor law violations, disorderly conduct, and drunkenness. Poisson estimates are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. The model includes day-of-panel and zone-month fixed effects. Standard errors are clustered by zone, with 95% confidence intervals provided.

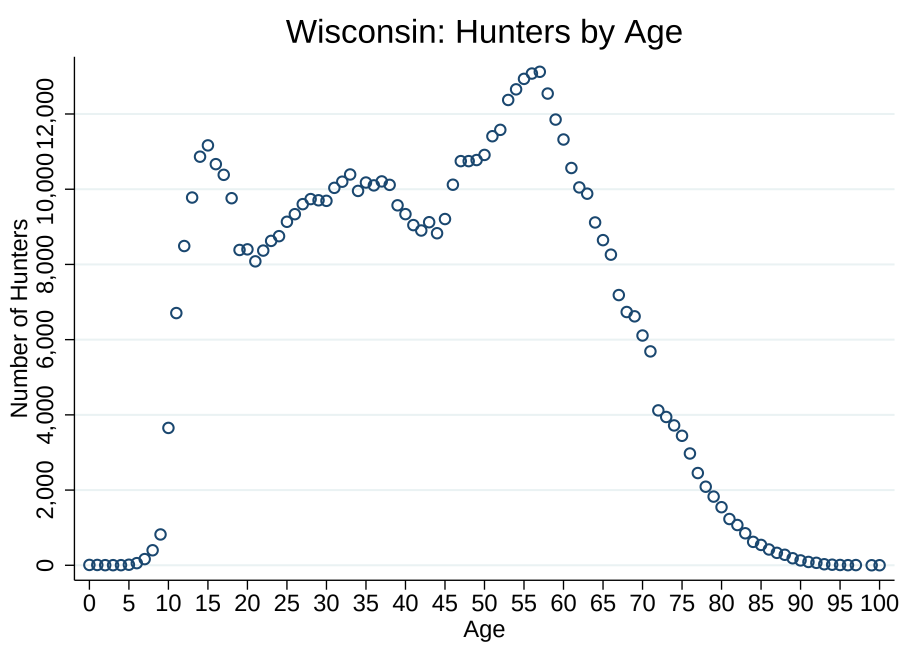
1.9 Appendix

Figure 1.A1: Hunting Demographics

(a) Percent of US Who Hunt by Age



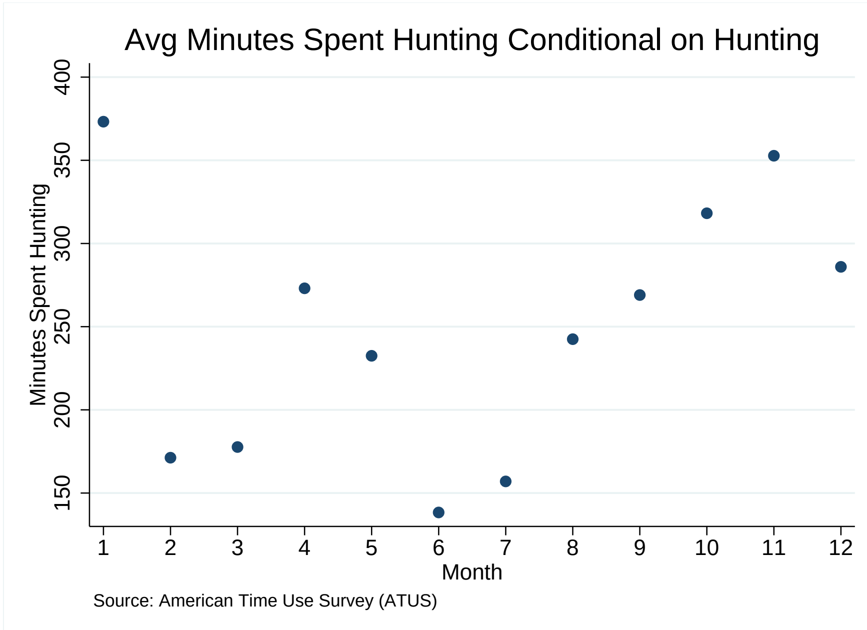
(b) Wisconsin Hunting Permits by Age



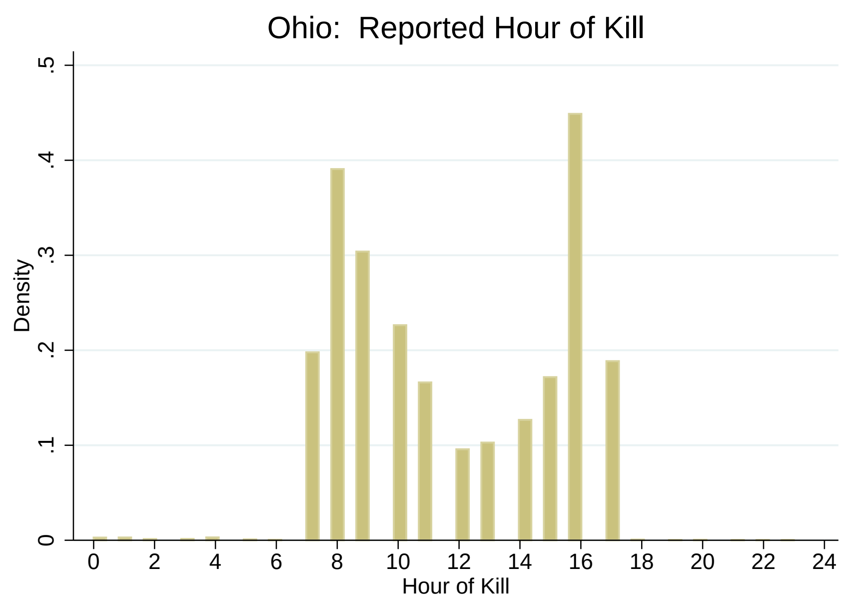
Notes: Data from 2011 US FHWAR and the Wisconsin DNR.

Figure 1.A2: Hunting Time Use

(a) Hours Spent Hunting



(b) Ohio: Harvests Reported by Hour of Kill



Notes: Data used in Panel (a) are from the American Time Use Survey (ATUS). Data used in Panel (b) are from Ohio Department of Natural Resources

Figure 1.A3: Example of Firearm Hunting Season Opening Days (2015)

2015 OCTOBER MONDAY

CALENDAR YEAR CALENDAR MONTH FIRST DAY OF WEEK

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
28	29	30	01	02	03	04
05	06	07	08	09	10 Idaho (Zone 2)	11 South Carolina (Zones 1-2)
12	13	14	15	16	17	18
19	20	21	22	23	24 Montana	25
26	27	28	29	30	31	01
02	03	04	05	06	07	08

2015 NOVEMBER MONDAY

CALENDAR YEAR CALENDAR MONTH FIRST DAY OF WEEK

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
26	27	28	29	30	31	01 SD (Black Hills)
02 Maine	03	04	05	06 North Dakota	07 Texas Minnesota SD (other)	08
09	10	11 New Hampshire	12	13	14 Vermont, Kentucky Arkansas, Indiana, Virginia, SD (West)	15 Michigan
16	17	18	19	20 Illinois	21 Wisconsin, New York, Tennessee, SD (East River)	22
23 West Virginia	24	25	26	27	28	29
30 Pennsylvania Ohio Massachusetts	01	02	03	04	05	06

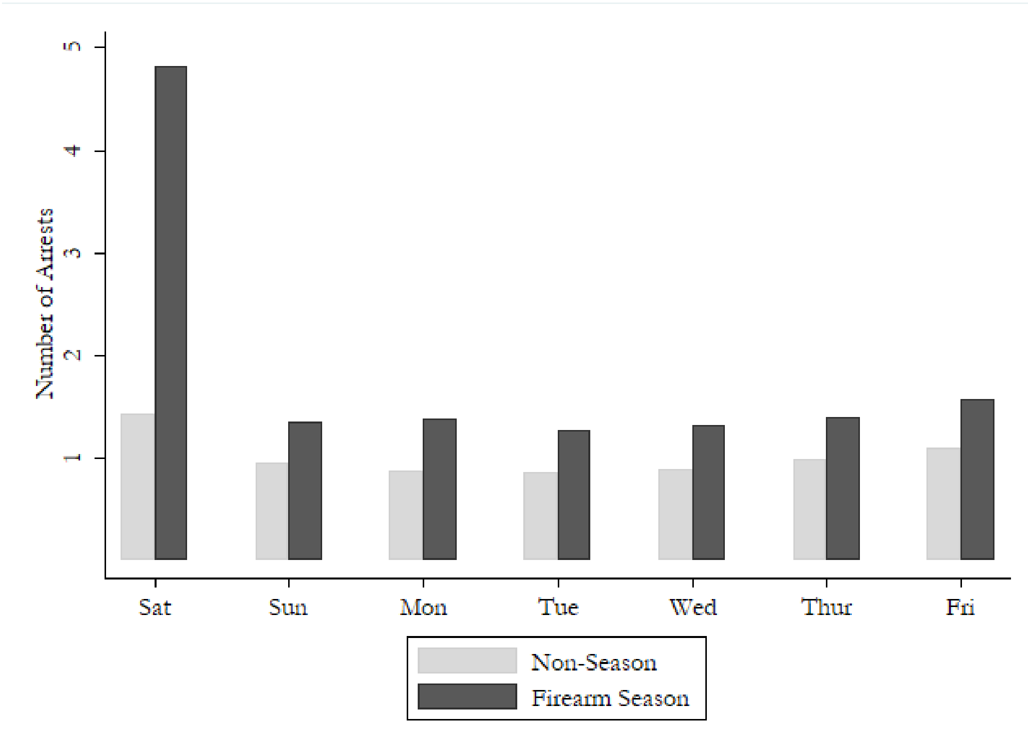
2015 DECEMBER MONDAY

CALENDAR YEAR CALENDAR MONTH FIRST DAY OF WEEK

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
30	01	02 Kansas	03	04	05 Iowa	06
07	08	09	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	01	02	03
04	05	06	07	08	09	10

Figure 1.A4: Rural Male Arrests in Zones Opening on Saturday

(a) Number of Armed Arrestees



(b) Number of Violent Crime Arrests

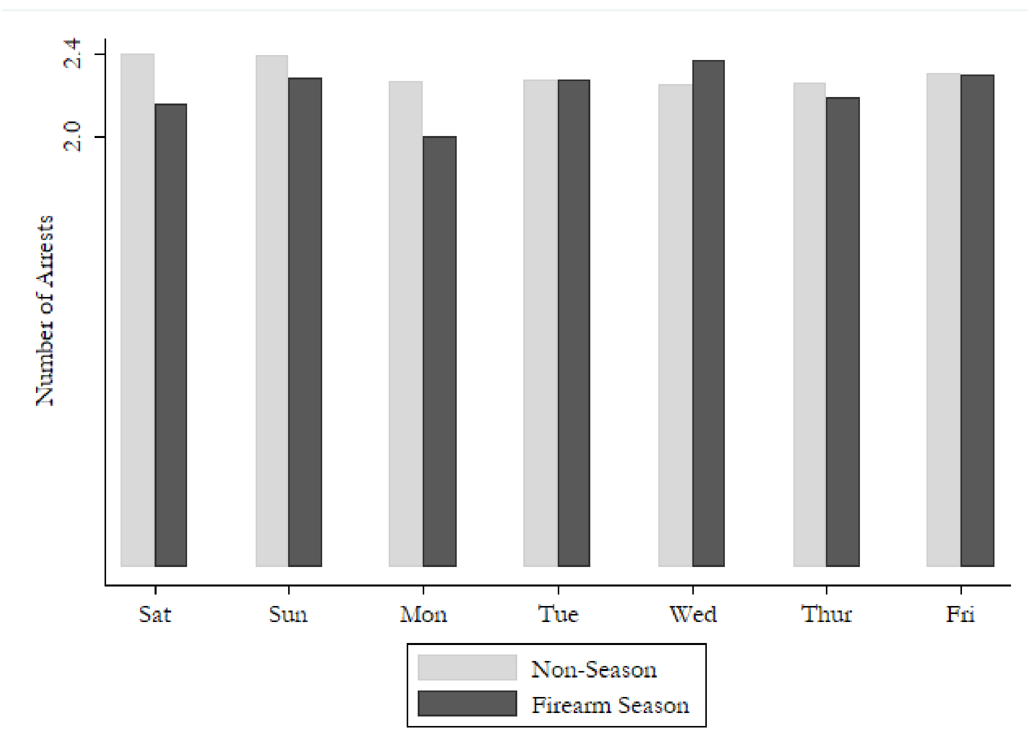
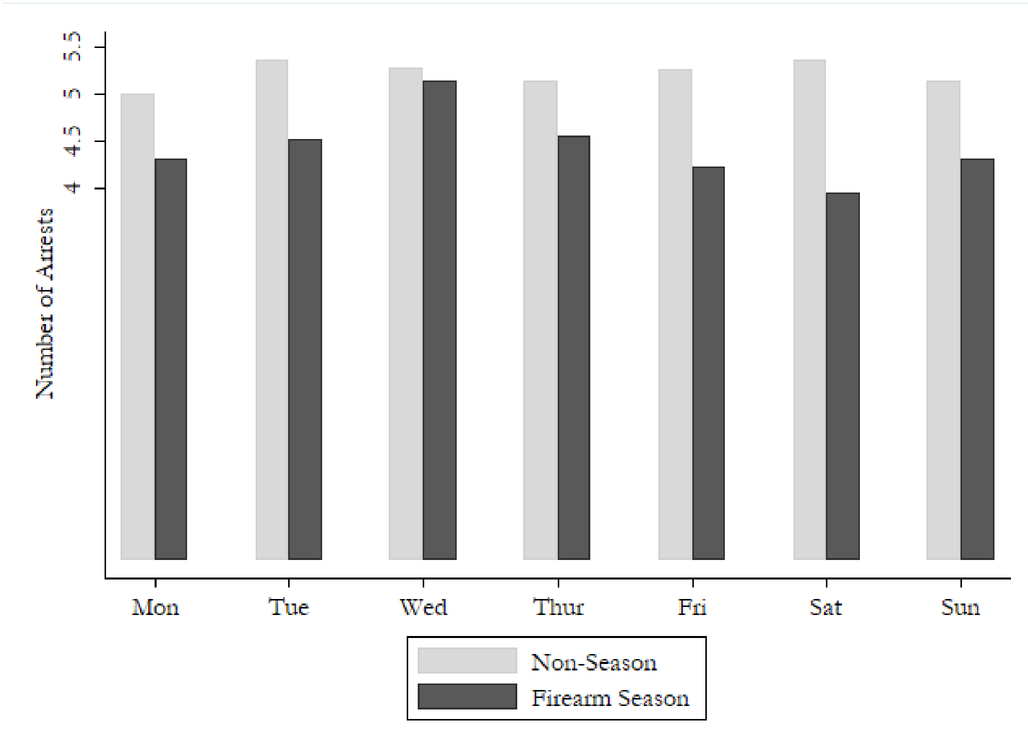


Figure 1.A5: Urban Male Arrests in Zones Opening on Monday

(a) Number of Armed Arrestees



(b) Number of Violent Crime Arrests

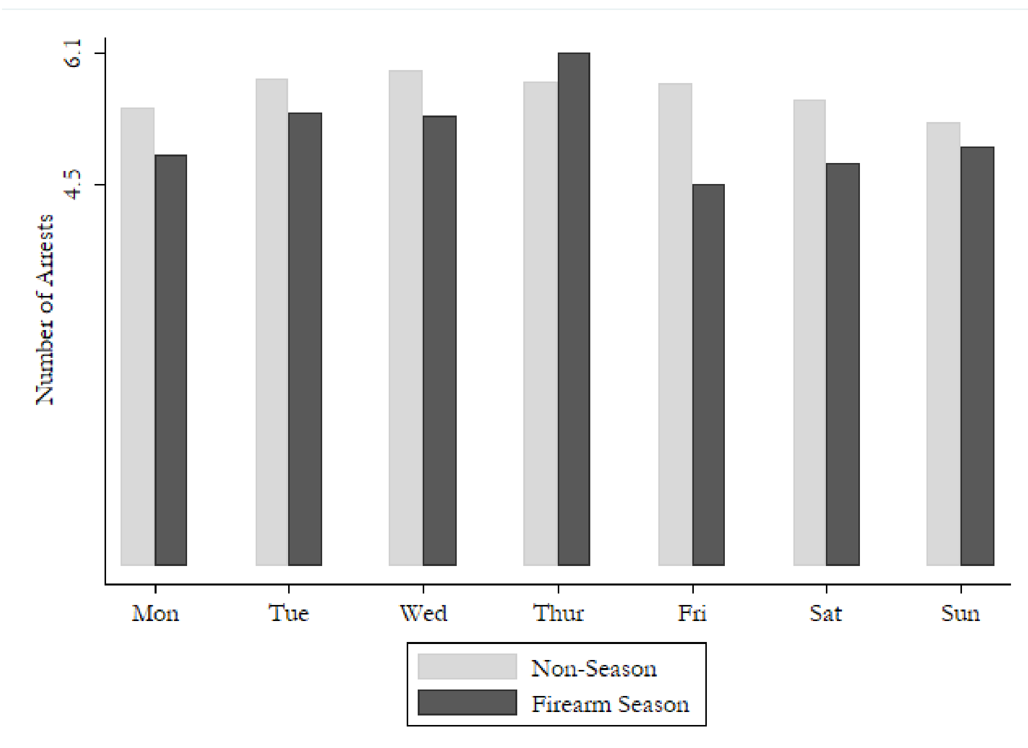
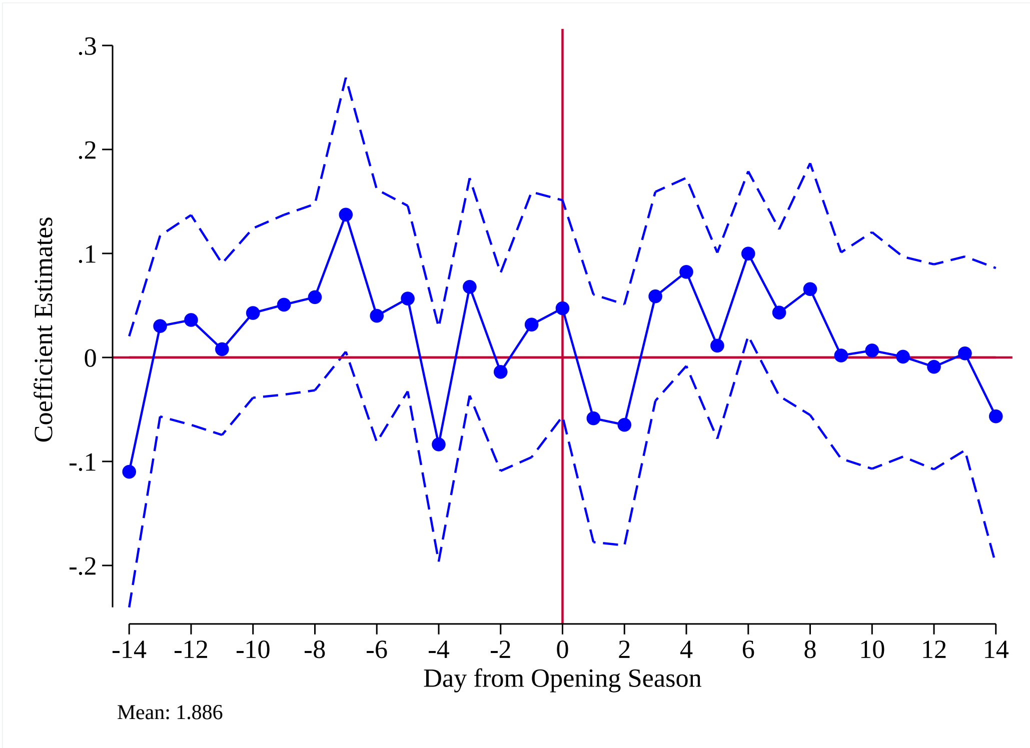


Figure 1.A6: Estimated Effects of Firearm Season on Rural Male Violent Crime

(a) Violent Crime Arrests



(b) Violent Crime Offenses

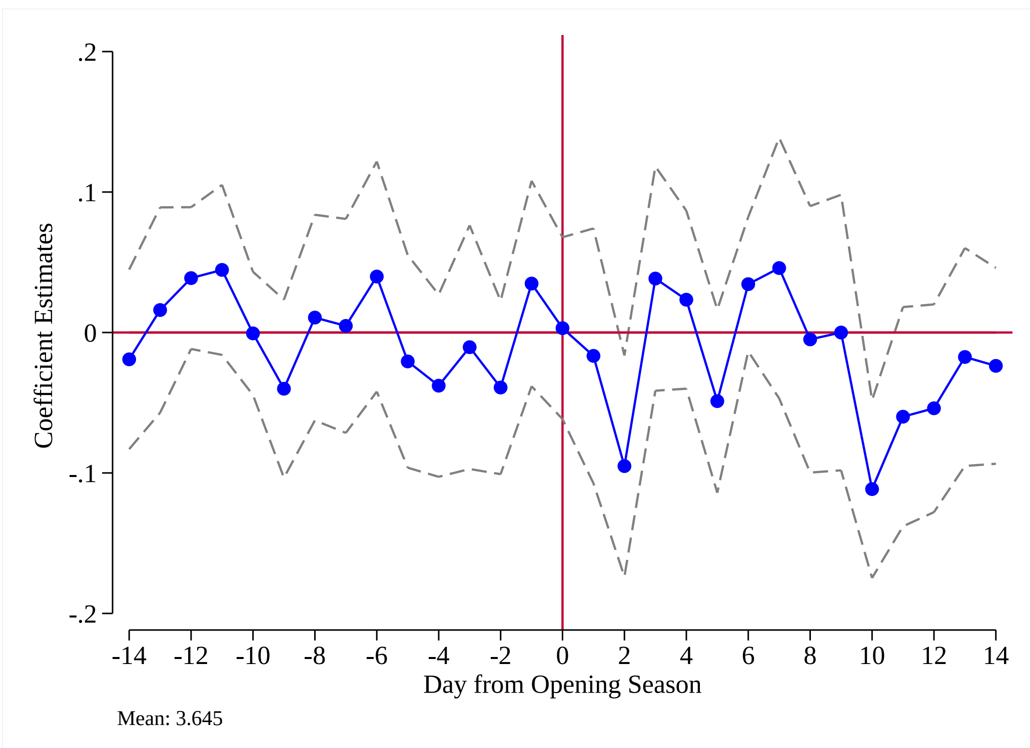
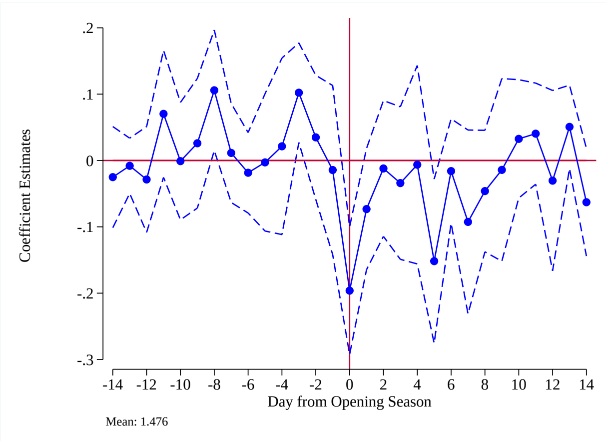
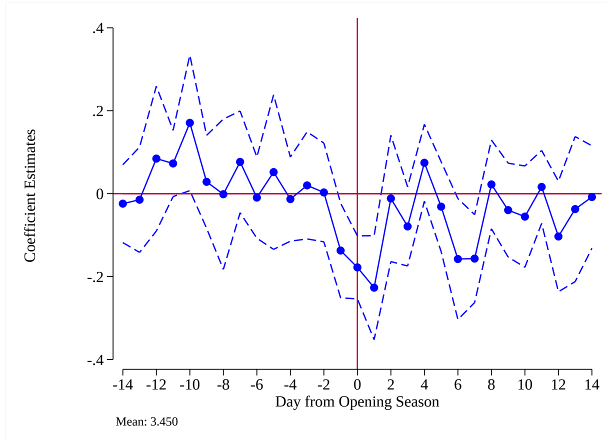


Figure 1.A7: Male 21 & Under Alcohol-Related Arrests

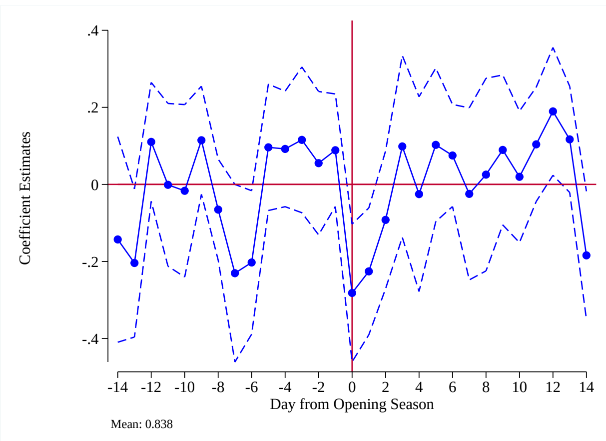
(a) Driving Under the Influence



(b) Liquor Law Violation



(c) Disorderly Conduct



(d) Drunkenness

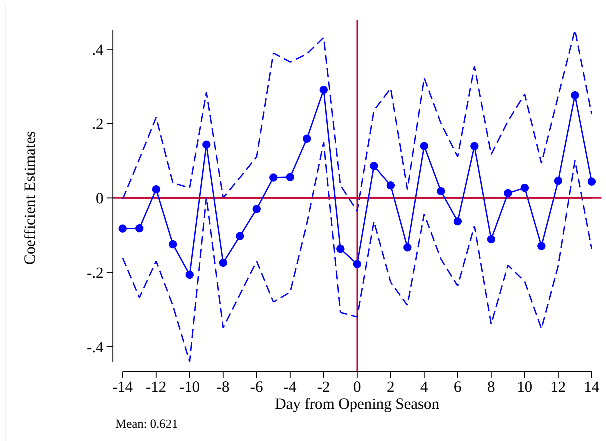


Table 1.A1: NIBRS State Coverage

State	Certification Date	Number of Agencies	Percent of Population	Percent of State Crime	In Sample?
Arizona	7/04	7	6%	2%	N
Arkansas	4/00	295	100%	100%	Y
Colorado	11/97	227	90%	88%	N
Connecticut	7/99	102	75%	59%	N
Delaware	7/01	71	100%	100%	N
Idaho	7/92	142	100%	100%	Y
Iowa	8/92	253	100%	100%	Y
Kansas	2/01	432	90%	73%	Y
Kentucky	1/05	548	83%	63%	Y
Louisiana	1/02	45	16%	12%	N
Maine	7/03	24	23%	25%	Y
Massachusetts	8/95	309	86%	82%	Y
Michigan	2/96	802	100%	100%	Y
Missouri	7/05	22	11%	17%	N
Montana	7/00	121	100%	100%	Y
Nebraska	2/97	116	39%	23%	N
New Hampshire	5/03	227	100%	100%	Y
North Dakota	2/91	127	100%	100%	Y
Ohio	1/99	704	83%	71%	Y
Oklahoma	10/09	248	28%	11%	N
Oregon	6/97	87	29%	28%	N
Rhode Island	5/02	60	100%	100%	N
South Carolina	1/91	535	100%	100%	Y
South Dakota	2/01	161	100%	100%	Y
Tennessee	7/98	579	100%	100%	Y
Texas	7/98	104	22%	13%	Y
Utah	4/94	104	81%	86%	N
Vermont	4/94	91	100%	100%	Y
Virginia	11/94	450	100%	100%	Y
Washington	2007	194	45%	34%	N
West Virginia	9/98	514	100%	100%	Y
Wisconsin	2/97	94	38%	45%	Y

Notes: Data are from the Justice Research and Statistics Association (JRSA).

Table 1.A2: Estimated Effects of Firearm Season on Male Rural Crime

	(1)	(2)	(3)
Sex Offenses			
3-5 Days Before	-0.0590	0.00188	-0.00124
	(0.0490)	(0.0560)	(0.0570)
1-2 Days Before	0.0869	0.0988**	0.0949**
	(0.0570)	(0.0463)	(0.0445)
Opening 2 Days	0.00498	-0.0530	-0.0607
	(0.0558)	(0.0518)	(0.0507)
3-4 Days After	0.00490	-0.0136	-0.0230
	(0.0404)	(0.0311)	(0.0285)
5-7 Days After	0.0291	0.0302	0.0203
	(0.0610)	(0.0424)	(0.0430)
Observations	135,969	135,579	127,345
Simple Assaults & Intimidation			
3-5 Days Before	-0.0166	-0.00135	-0.00109
	(0.0106)	(0.0122)	(0.0115)
1-2 Days Before	-0.00451	-0.00175	-0.00157
	(0.00981)	(0.0133)	(0.0128)
Opening 2 Days	-0.00676	-0.00465	-0.00502
	(0.0119)	(0.0126)	(0.0138)
3-4 Days After	-0.0142	-0.0174	-0.0171
	(0.0124)	(0.0137)	(0.0127)
5-7 Days After	0.00739	0.00272	0.00285
	(0.0124)	(0.00879)	(0.00878)
Observations	135,969	135,604	129,910
Weapon Law Violations			
3-5 Days Before	-0.00769	0.0150	-0.0220
	(0.0291)	(0.0340)	(0.0350)
1-2 Days Before	0.0196	0.0233	-0.0141
	(0.0453)	(0.0517)	(0.0570)
Opening 2 Days	0.249***	0.278***	0.245***
	(0.0771)	(0.0806)	(0.0762)
3-4 Days After	0.0858	0.0990*	0.0430
	(0.0648)	(0.0570)	(0.0576)
5-7 Days After	0.104***	0.137***	0.0856*
	(0.0281)	(0.0425)	(0.0455)
Observations	135,969	135,589	123,954
Zones	29	29	29
Day-of-Week FE	Yes	No	No
Week-of-Year FE	Yes	No	No
Year FE	Yes	No	No
Day-of-Panel FE	No	Yes	Yes
Zone FE	No	Yes	No
Zone-by-Month FE	No	No	Yes

Notes: Test. Sex offenses include rape, sexual assault with an object, fondling, and sodomy. Standard errors clustered at the zone level. Poisson estimates are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. *** p<0.01, ** p<0.05, * p<0.1

Table 1.A3: Effects on Rural Male 21 & Under Alcohol Arrests by Opening Day

	(1)	(2)	(3)
Alcohol-Related Arrests: Weekend Open			
3-5 Days Before	-0.0420	0.0866**	0.101***
	(0.0565)	(0.0359)	(0.0359)
1-2 Days Before	-0.0646**	-0.0987***	-0.0700***
	(0.0325)	(0.0197)	(0.0213)
Opening 2 Days	-0.158***	-0.190***	-0.175***
	(0.0318)	(0.0370)	(0.0345)
3-4 Days After	-0.0496	0.0363	0.0655
	(0.0473)	(0.0485)	(0.0458)
5-7 Days After	-0.0420	-0.0716	-0.0435
	(0.0415)	(0.0556)	(0.0506)
Observations	72,310	71,943	69,633
Zones	22	22	22
Alcohol-Related Arrests: Weekday Open			
3-5 Days Before	0.0104	-8.36e-05	0.0291
	(0.0632)	(0.0546)	(0.0552)
1-2 Days Before	-0.0230	0.0330	0.0424
	(0.0393)	(0.0568)	(0.0662)
Opening 2 Days	-0.204***	-0.123	-0.124
	(0.0736)	(0.0863)	(0.0921)
3-4 Days After	-0.0289	-0.0624	-0.0455
	(0.0504)	(0.0441)	(0.0530)
5-7 Days After	-0.0183	-0.0352	-0.0408
	(0.0378)	(0.0420)	(0.0459)
Observations	55,147	55,137	53,297
Zones	17	17	17
Day-of-Week FE	Yes	No	No
Week-of-Year FE	Yes	No	No
Year FE	Yes	No	No
Day-of-Panel FE	No	Yes	Yes
Zone FE	No	Yes	No
Zone-by-Month FE	No	No	Yes

Notes: A zone-year is defined as a weekend opening if the zone opens season on a Friday, Saturday, or Sunday. Alcohol-related arrests include arrests for driving under the influence (DUI), liquor law violations, disorderly conduct, and drunkenness. Standard errors clustered at the zone level. Poisson estimates are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. *** p<0.01, ** p<0.05, * p<0.1

Table 1.A4: Firearm Season and Male Urban Crime

	(1)	(2)	(3)
Armed Arrestees (Long)			
3-5 Days Before	0.101	0.184	0.257
	(0.112)	(0.180)	(0.171)
1-2 Days Before	-0.467*	-0.452*	-0.322
	(0.269)	(0.258)	(0.250)
Opening 2 Days	-0.119	-0.300	-0.128
	(0.189)	(0.187)	(0.138)
3-4 Days After	-0.336*	-0.487***	-0.441*
	(0.178)	(0.179)	(0.239)
5-7 Days After	-0.332*	-0.374	-0.214
	(0.183)	(0.235)	(0.255)
Observations	76,365	45,469	23,501
Violent Crime Offenses			
3-5 Days Before	-0.0544**	-0.0225	-0.0246*
	(0.0253)	(0.0142)	(0.0146)
1-2 Days Before	-0.00680	-0.0159	-0.0233*
	(0.0136)	(0.0128)	(0.0126)
Opening 2 Days	0.00406	-0.00483	0.00944
	(0.0268)	(0.0294)	(0.0267)
3-4 Days After	0.0451***	0.0321**	0.0385***
	(0.0140)	(0.0144)	(0.0133)
5-7 Days After	-0.0216	-0.0137	-0.0214
	(0.0181)	(0.0182)	(0.0195)
Observations	78,736	78,719	78,100
Alcohol-Related Arrests			
3-5 Days Before	0.0103	0.0220	0.0183
	(0.0243)	(0.0220)	(0.0202)
1-2 Days Before	-0.0129	0.00452	-0.00272
	(0.0309)	(0.0317)	(0.0283)
Opening 2 Days	-0.0181	-0.0470	-0.0531
	(0.0322)	(0.0448)	(0.0406)
3-4 Days After	-0.0244	-0.00804	-0.0157
	(0.0275)	(0.0315)	(0.0302)
5-7 Days After	-0.0431*	-0.0523**	-0.0593**
	(0.0236)	(0.0266)	(0.0268)
Observations	76,365	76,361	75,689
Zones	18	18	18
Day-of-Week FE	Yes	No	No
Week-of-Year FE	Yes	No	No
Year FE	Yes	No	No
Day-of-Panel FE	No	Yes	Yes
Zone FE	No	Yes	No
Zone-by-Month FE	No	No	Yes

Notes: Urban jurisdictions are defined as law enforcement agencies covering a population of more than 250,000. Violent crime offenses are an aggregation of reported aggravated assault, murder, rape, and robbery. Alcohol-related arrests include arrests for driving under the influence (DUI), liquor law violations, disorderly conduct, and drunkenness. Standard errors clustered by zone. Poisson estimates are reported, implying that percent effects are $(e^{\beta} - 1)$ x 100%. *** p<0.01, ** p<0.05, * p<0.1

Table 1.A5: Linear Probability Model: Male Arrestees Armed with Long Gun

VARIABLES	(1) 1+	(2) 2+	(3) 3+	(4) 4+	(5) 5+
OD-5	-0.0105	0.00926	0.00531	0.00832	-0.00655
	(0.0206)	(0.0154)	(0.0144)	(0.0176)	(0.00960)
OD-4	-0.00228	-0.00321	-0.00537	0.000174	-0.00664
	(0.0193)	(0.0121)	(0.00622)	(0.00726)	(0.00943)
OD-3	0.00305	0.0163	0.00879	0.00890	0.00385
	(0.0169)	(0.0153)	(0.0171)	(0.0138)	(0.0133)
OD-2	-0.0297*	0.0123	0.0117	0.0127	0.0117
	(0.0162)	(0.0199)	(0.0182)	(0.0152)	(0.0128)
OD-1	0.00278	0.00557	0.0101	0.0159	0.0216
	(0.0173)	(0.0150)	(0.0148)	(0.0161)	(0.0172)
Opening Day	0.0920***	0.0750***	0.0398*	0.0441	0.0444
	(0.0246)	(0.0220)	(0.0222)	(0.0272)	(0.0304)
OD+1	0.0650***	0.0438**	0.0454	0.0488	0.0448
	(0.0216)	(0.0212)	(0.0283)	(0.0320)	(0.0322)
OD+2	0.0186	0.0283	0.0391*	0.0479	0.0421
	(0.0146)	(0.0174)	(0.0226)	(0.0282)	(0.0295)
OD+3	0.000817	0.0330*	0.0408**	0.0455**	0.0429**
	(0.0189)	(0.0185)	(0.0197)	(0.0220)	(0.0207)
OD+4	0.0588**	0.0428*	0.0395*	0.0382	0.0347
	(0.0270)	(0.0243)	(0.0214)	(0.0227)	(0.0204)
OD+5	0.0606***	0.0465**	0.0334	0.0283	0.0314
	(0.0189)	(0.0186)	(0.0239)	(0.0231)	(0.0250)
OD+6	0.0140	0.0205**	0.0249*	0.0162	0.0148
	(0.0187)	(0.00961)	(0.0123)	(0.0103)	(0.00873)
Observations	131,726	131,726	131,726	131,726	131,726
R-squared	0.272	0.285	0.309	0.324	0.326
Mean	0.122	0.0344	0.0148	0.00864	0.00594

Notes: The dependent variable is a binary denoting whether a zone-day has 1+ ($\geq$ 1) armed arrestees. The model includes day-of-panel and zone-month fixed effects. Standard errors clustered by zone. *** p<0.01, ** p<0.05, * p<0.1

Table 1.A6: Linear Probability Model: Male Violent Crime Offenses

	(1)	(2)	(3)	(4)	(5)
VARIABLES	1+	2+	3+	4+	5+
OD-5	0.0181	0.0268	-0.00374	-0.0253	-0.0232
	(0.0161)	(0.0184)	(0.0214)	(0.0217)	(0.0168)
OD-4	-0.00373	-0.0273	-0.0197	-0.0204	-0.0252
	(0.0223)	(0.0207)	(0.0188)	(0.0162)	(0.0157)
OD-3	-0.00429	0.00854	-0.0242	-0.0238	-0.0211
	(0.0185)	(0.0223)	(0.0284)	(0.0178)	(0.0199)
OD-2	-0.0169	-0.0150	-0.0339	-0.0462*	-0.0106
	(0.0224)	(0.0235)	(0.0203)	(0.0229)	(0.0179)
OD-1	0.000261	-0.00204	-0.00623	0.00589	0.00823
	(0.0152)	(0.0179)	(0.0180)	(0.0215)	(0.0213)
Opening Day	0.00336	-0.00499	-0.00908	-0.0207	0.00492
	(0.0195)	(0.0222)	(0.0202)	(0.0141)	(0.0188)
OD+1	0.00815	0.0256	-0.0131	0.00296	-0.00223
	(0.0186)	(0.0189)	(0.0212)	(0.0245)	(0.0184)
OD+2	0.0106	-0.0149	-0.0452**	-0.0428**	-0.0320*
	(0.0156)	(0.0182)	(0.0187)	(0.0167)	(0.0171)
OD+3	-0.00118	0.0290	0.0298	0.0150	0.0219
	(0.0189)	(0.0221)	(0.0178)	(0.0162)	(0.0182)
OD+4	-0.0205	0.0127	0.00402	0.0194	0.0206
	(0.0146)	(0.0227)	(0.0225)	(0.0182)	(0.0200)
OD+5	-0.0187	-0.0223	-0.0178	-0.0137	-0.0104
	(0.0165)	(0.0247)	(0.0258)	(0.0195)	(0.0192)
OD+6	-0.0171	0.00171	0.0272*	0.0324	0.0410**
	(0.0168)	(0.0151)	(0.0153)	(0.0209)	(0.0154)
Observations	130,071	130,071	130,071	130,071	130,071
R-squared	0.485	0.584	0.634	0.645	0.629
Mean	0.769	0.600	0.475	0.381	0.306

Notes: The dependent variable is a binary denoting whether a zone-day has 1+ (≥ 1) violent crime offenses, for example. The model includes day-of-panel and zone-month fixed effects. Violent crime offenses are an aggregation of reported aggravated assault, murder, rape, and robbery. Standard errors clustered by zone. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 1.A7: Linear Probability Model: Male Alcohol-Related Arrests

VARIABLES	(1) 1+	(2) 5+	(3) 10+	(4) 15+	(5) 20+	(6) 25+
OD-5	-0.0133**	0.00812	0.0547*	0.0785*	0.0505	0.00114
	(0.00619)	(0.0191)	(0.0306)	(0.0419)	(0.0368)	(0.0280)
OD-4	0.00900	-0.0256	-0.00638	0.0426	0.0358	0.0409
	(0.00868)	(0.0287)	(0.0267)	(0.0352)	(0.0382)	(0.0426)
OD-3	0.00619	-0.0203	0.0267	0.0388	0.0523	0.00339
	(0.00640)	(0.0197)	(0.0214)	(0.0241)	(0.0334)	(0.0343)
OD-2	-0.00349	0.00585	-0.0279	-0.00611	0.00442	0.00204
	(0.00975)	(0.0286)	(0.0228)	(0.0342)	(0.0364)	(0.0298)
OD-1	-0.00274	-0.000866	-0.0466*	-0.0354	-0.0193	-0.0164
	(0.00588)	(0.0175)	(0.0248)	(0.0327)	(0.0343)	(0.0273)
Opening Day	0.00616	0.0310	-0.0560*	-0.0798**	-0.0767**	-0.0650**
	(0.0127)	(0.0209)	(0.0286)	(0.0341)	(0.0358)	(0.0303)
OD+1	-0.00827	0.0141	-0.00902	-0.0380	-0.0449	-0.0285
	(0.0115)	(0.0171)	(0.0168)	(0.0280)	(0.0291)	(0.0316)
OD+2	0.0243*	-0.0154	0.0275	0.0347	0.000485	-0.0191
	(0.0140)	(0.0254)	(0.0243)	(0.0276)	(0.0234)	(0.0256)
OD+3	0.0112	-0.0154	-0.0151	0.0211	0.0225	0.0117
	(0.0126)	(0.0211)	(0.0201)	(0.0228)	(0.0374)	(0.0420)
OD+4	-0.0139	0.00114	-0.00991	0.0191	0.0193	0.0172
	(0.0156)	(0.0199)	(0.0209)	(0.0334)	(0.0387)	(0.0397)
OD+5	0.00910	0.0191	-0.0495**	-0.0515	-0.00524	0.00934
	(0.0111)	(0.0210)	(0.0217)	(0.0334)	(0.0373)	(0.0343)
OD+6	0.00475	0.00199	-0.0607**	-0.0418	-0.0146	0.00117
	(0.00720)	(0.0173)	(0.0290)	(0.0286)	(0.0269)	(0.0259)
Observations	131,726	131,726	131,726	131,726	131,726	131,726
R-squared	0.404	0.603	0.653	0.680	0.687	0.676
Mean	0.960	0.793	0.567	0.432	0.341	0.278

Notes: The dependent variable is a binary denoting whether a zone-day has 1+ (≥ 1) alcohol-related arrests, for example. The model includes day-of-panel and zone-month fixed effects. Alcohol-related arrests include arrests for driving under the influence (DUI), liquor law violations, disorderly conduct, and drunkenness. Standard errors clustered by zone. *** p<0.01, ** p<0.05, * p<0.1

Table 1.A8: Linear Probability Model: Male Narcotic Arrests

VARIABLES	(1) 1+	(2) 2+	(3) 3+	(4) 4+	(5) 5+
OD-5	-0.00853	-0.0160	0.00911	-0.00457	0.0114
	(0.0125)	(0.0194)	(0.0139)	(0.0148)	(0.0169)
OD-4	-0.00983	-0.0134	0.00834	0.00201	0.00345
	(0.0163)	(0.0242)	(0.0203)	(0.0193)	(0.0183)
OD-3	0.0488**	0.00194	0.0150	-0.0122	0.00153
	(0.0184)	(0.0202)	(0.0226)	(0.0167)	(0.0156)
OD-2	0.0130	0.0240	-0.00116	0.00748	0.00807
	(0.0173)	(0.0190)	(0.0176)	(0.0199)	(0.0226)
OD-1	-0.0123	-0.0490**	-0.0177	-0.00858	-0.0221
	(0.0171)	(0.0193)	(0.0195)	(0.0212)	(0.0205)
Opening Day	0.00449	-0.0300*	-0.0301**	-0.0220	-0.0468**
	(0.0155)	(0.0148)	(0.0132)	(0.0184)	(0.0194)
OD+1	0.0316**	-0.00624	-0.00827	-0.0260	-0.0468**
	(0.0139)	(0.0253)	(0.0249)	(0.0211)	(0.0225)
OD+2	-0.00296	1.42e-05	-0.0202	-0.00734	-0.00234
	(0.0148)	(0.0203)	(0.0173)	(0.0154)	(0.0177)
OD+3	0.0140	-0.0323	-0.0165	-0.0167	-0.0252
	(0.0198)	(0.0192)	(0.0197)	(0.0191)	(0.0193)
OD+4	0.0452***	0.0245	-0.00788	-0.00495	-0.00603
	(0.0158)	(0.0204)	(0.0194)	(0.0243)	(0.0269)
OD+5	-0.00359	-0.00154	-0.00844	-0.0185	-0.0205
	(0.0197)	(0.0223)	(0.0194)	(0.0184)	(0.0170)
OD+6	0.0360*	0.0231	-0.00635	-0.0319*	-0.0349*
	(0.0178)	(0.0160)	(0.0161)	(0.0173)	(0.0174)
Observations	136,250	136,250	136,250	136,250	136,250
R-squared	0.463	0.487	0.522	0.555	0.582
Mean	0.829	0.719	0.621	0.539	0.471

Notes: The dependent variable is a binary denoting whether a zone-day has 1+ (≥ 1) narcotic arrests, for example. The model includes day-of-panel and zone-month fixed effects. Standard errors clustered by zone. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

CHAPTER 2

BAKKEN OUT OF EDUCATION TO TOIL IN OIL

2.1 Introduction

I utilize the recent North Dakota oil and natural gas boom to analyze the effects of changing local labor market conditions on the demand for education. Between 2007 and 2013, both average weekly wages and employment levels in counties with wells in the Bakken Formation doubled (Figure 2.2 and Figure 2.3). Williams County was the heart of the oil patch where the civilian labor force increased over 330% from 15,000 in 2008 to 50,000 in 2013 (Williston Impact Statement (2014)). High wages and housing prices were a new pattern that emerged across northwestern North Dakota. Figure 2.1 illustrates the impact of the oil boom on county level unemployment rates (overlaid with oil rig and school district locations). The boom centralized around Williston (yellow star), a booming city highlighted *ad nauseam* in the news.[1] The oil boom provides a plausibly exogenous shock to local labor market conditions that can be exploited to study effects on educational attainment decisions.

The 21st century fracking boom created a low-skilled labor demand shock with the strongest impacts on young males without a college degree (Fetzer, 2014; Cascio and Narayan, 2015; Wilson, 2016; Kearney and Wilson, 2018). Specifically, Fetzer (2014) found the largest employment and earnings effects for workers without a high school degree, followed by those with only a high school degree or equivalent. Many jobs created by the oil boom were low-skill jobs on oil rigs, trucking routes, warehousing, and other service sector jobs. Higher low-skill wages may lure students out of high school and deter students from enrolling in college or the military. The average unemployment rate in North Dakota's top four oil producing counties decreased from 3.65% in 2007 to 1.4% in 2012 and was 1.45% as of 2014. Throughout the same time period,

[1] News articles by Reuters, CNN Money, CNBC, LA Times, New York Times, etc

the average unemployment rate of North Dakota's remaining 49 counties actually increased from 3.73% to 3.79%.[2] The increase in low-skill labor employment and wages creates a substitution effect that incentivizes high school graduates to forgo college or the military and enter the labor force instead.

Although the boom created incentives to forgo college, it may also have created conditions to encourage further education. With higher income, families may place greater value on college education or are better able to finance it, thereby making a high school graduate more likely to enroll in college. There is high correlation between family income and educational attainment, which may counteract the substitution effect of higher wages (Blanden and Gregg (2004)). Additionally, better financed high schools and scholarship funding may increase college enrollment. According to ND Office of the Governor, oil tax revenues have created an unprecedented government budget surplus, allowing the state to appropriate greater funding to school districts, higher education grants, and need-based scholarships (Dakota, 2013). Increases in high school funding and higher education grants may make a student more likely to graduate from high school and more likely to enroll in college. These conflicting effects that may encourage or discourage an adolescent from continuing their education imply that net impacts can only be understood through empirical analysis.

The ND oil boom is an ideal natural experiment to analyze the impact of a changing local economy on educational attainment. Prior to 2014, the oil boom was expected to last at least 20 to 30 years (under the crucial assumption that crude prices remained above $60 per barrel) with estimates up to 100 years as echoed in the New York Times (Brown, 2013). This unpredicted economic shock would have a significant long term impact on expected individual lifetime earnings. However, in 2014 and 2015, market determined crude oil prices drastically dropped from $100 to under $50 per barrel, reducing ND extraction profit margins and placing many rigs below break-even prices.

In conjunction with the boom having an abrupt start, the boom was focused in northwestern

[2] North Dakota's top four oil producing counties are Dunn, McKenzie, Mountrail, and Williams

ND, which traditionally had a population density less than ten people per square mile (fourth lowest in the U.S.). In 2008, ND had a total population of 641,481 residents, 40 percent of whom lived in only four cities. In 2014, the US Census Bureau estimate of North Dakota's population was 739,482, giving the state one of the highest population growth rates in the United States in contrast to its late twentieth and early twenty-first century population stagnation. Low population density and a geographically large state help define an affected local labor market (northwestern ND) in contrast to other less affected areas in eastern ND (with towns up to 450 road-miles away from Williston).

This paper analyzes the impact of the North Dakota oil boom on two educational attainment decisions: high school graduation and post-graduation plans. To empirically examine the effect of the boom on educational choices, I use a difference in difference research design paired with event-study analyses (Jacobson et al., 1993). I use yearly oil production data to differentiate between the pre-boom and post-boom period and compare outcomes in core-oil producing counties relative to low or non-producing counties. Economic theory suggests that schools in the proximity of the oil boom centroid are those most impacted by the boom. As distance from the oil boom increases, so do commute times. Individuals further from the boom have longer commutes and must leave social networks and are less likely to have social connections in the oil drilling area. Identification hinges on comparing outcomes in schools within core-oil counties versus non-oil counties before and after the oil boom.

I find that the ND oil boom had no discernible effect on high school graduation rates within core-oil producing counties. Event-study analyses provide no evidence that the oil boom had any negative effect on core-oil high school graduation rates or males or females. However, results suggest that the oil boom had a strong impact on post-graduation educational outcomes of both genders. Event-study figures clearly show that the oil boom had a large, negative effect on 4 year college enrollment rates. DD estimates imply that 4 year college enrollment rates decreased 12 percentage points (23%) in core-oil counties relative to non-oil counties. Surprisingly, core-oil county enrollment rates at North Dakota research universities dropped 25%, suggesting even higher skill students can be on the margin between attending 4 year university and taking a job out of high school. Results using administrative high school data reaffirm that high school seniors decreased college enrollment rates. Evidence suggests that both males and females in core-oil counties became more likely to enter the labor force upon graduation while males became less likely to enroll in the military. The decrease in male military enrollment may be because both military and fracking related work are largely dominated by young males. My results suggest that there are many North Dakota students on the margin between post-graduation plans while there are few students making marginal decisions concerning high school graduation.

This paper provides three key contributions to the existing literature. First, to this author's knowledge, this is the first paper to analyze the effect of a natural resource boom on both high school graduation rates and post-graduation decisions of the same population. Previous research focuses almost purely on high school graduation rates. The results of this paper suggest that an economic shock is able to have little effect on high school graduation rates, while strongly impacting post-graduation plans. Second, this paper studies both male *and* female outcomes. Previous work focuses on male outcomes or male-female gaps in education because natural resource booms are usually male and low-skill biased. However, I provide clear evidence that the North Dakota oil boom also created strong growth in non-oil sectors with higher female participation rates, implying that female educational decisions should also be studied. Third, the paper exploits previously unused data from the North Dakota Department of Public Instruction (NDDPI) to study a population that can't be studied via conventional surveys due to low sample size or privacy restrictions. This paper is of considerable interest due to its policy implications. Between 2014 and 2015 the ND oil boom frenzy calmed with the decrease in market crude oil prices. However, if crude oil prices increase above the break-even prices of more rigs, the oil boom will flare up again and high school students will face similar incentives. Regions that experience reductions in college enrollment rates in lieu of employment may benefit during the boom, but will be left with a surplus of low-skill unemployed workers when the boom goes bust.

2.2 Literature Review

2.2.1 Economic Conditions and Educational Attainment

Simple human capital models predict that students will attain less education when the rate of return on education falls. As public high school is free for students, forgone earnings are the greatest opportunity cost of earning a high school degree. Meanwhile, the opportunity cost of a college education is the sum of college tuition costs and forgone earnings. All else equal, economic theory predicts that an increase in the opportunity cost of a college degree will lower the rate of return on education and drive an individual to attain less education. Therefore, any economic shock that reduces the ratio of high school graduate to dropout earnings will reduce high school graduation rates and any shock that reduces the ratio of college graduate to high school graduate earnings will reduce college enrollment rates. Literature has studied this link by exploiting local area unemployment rates.

A wealth of research illustrates that there is countercyclical demand for education. Boffy-Ramirez et al. (2013) find that higher unemployment rates before high school graduation increase the amount of education a student receives and a student's probability of graduating from college for students in the fourth quintile of the Armed Forces Qualifying Test distribution. However, they do not find that higher unemployment rates affected the likelihood of high school graduation. Both Manski and Wise (1983) and Card and Lemieux (2001) find only weak evidence of a relationship between statewide unemployment and educational attainment while other studies find unemployment rates to have a significant positive effect on schooling (Dellas and Sakellaris (2003)).

Unemployment changes may have differing effects on demand for education depending on whether the change in labor demand occurred in high or low-skill jobs. Unemployment reductions driven by higher skill labor demand will not increase the opportunity cost of college because high school graduates are excluded from those jobs. High skill labor booms may actually incentivize individuals to pursue more education in order to obtain higher skill jobs. Natural resource booms like the ND oil boom tend to drive growth in low-skill labor demand, implying that the opportunity cost of college and military enrollment is impacted. Warner (2012) finds that a decrease in the civilian unemployment rate reduces high quality military recruits. As unemployment has fallen with the increase in demand for labor in northwest ND, we may expect military enrollment rates to decrease in areas affected by the oil boom.

Evans et al. (2006) claim that one commonality among papers that only find weak effects of local labor markets on educational attainment is that they measure labor markets on a statewide basis. Adolescents may make educational attainment decisions within their local labor markets, which may be smaller than the state in which they live. Even within a state, much heterogeneity of unemployment exists, which is especially true for a low density, large state like ND. Defining local labor markets at an area more granular than the state level also provides a large source of exogenous variation in labor market conditions. Therefore, many authors have investigated the subject using more granular data to define a local labor market. Rivkin (1995) discovered that higher county unemployment rates increased the likelihood of school enrollment for both high school and college students. Similarly, I will define treatment at the county level by using county level oil statuses designated by the state of North Dakota.

Research has also been conducted on local labor market shocks and demand for education. Evans et al. (2006) examined the impacts of federal legislation in 1988 that led to almost 400 Indian casino openings. Within rural local labor markets, Indian casinos improved employment and wages of lower skilled jobs. They found that adolescents were more likely to drop out of high school and less likely to enroll in college. The ND oil boom is similar in that it is focused in rural areas and increased low-skill employment levels and wages. My research is similar to that of Black et al. (2005) insofar as I examine the effects of a natural resource mining boom on demand for labor. They analyzed the impact of the Appalachian coal boom on high school enrollment rates, finding that increases in lower skilled employment and wages led to lower high school enrollment rates. My results suggest that the strong impact of the 1970s coal boom on high school graduation rates cannot be extrapolated to the modern day setting in ND. Most recently, Cascio and Narayan

(2015) find that fracking induced labor demand shocks particularly affect males and low-skilled labor. They find that fracking slowed the closing gap between male and female high school dropout rates. Additionally, the magnitude of the effect of fracking on dropout rates increases when they take North Dakota out of their sample. The null effects of fracking on high school dropouts I find in North Dakota support their results while also suggesting that interesting heterogeneous effects may exist. I contribute to this literature by using novel datasets that can hone in on rural areas with more precision than survey-based datasets. I expand analysis to both genders, as females may also be impacted by non-oil employment opportunities created by oil booms.

2.2.2 Effects of the 21st Century Fracking Boom

Others have used the recent nationwide fracking boom to study key outcomes like employment, migration, and crime. Feyrer et al. (2017) estimate that a million dollars of new fracking revenue drives over \$250,000 in wage growth and over \$280,000 in mineral rights royalty and business income within 100 miles of the fracking activity. Fetzer (2014) estimates that each additional fracking-related oil and gas job created another 2.17 non-mining jobs. The author found that the largest gains in employment and earnings, in both mining and non-mining sectors, were driven by individuals without a high school degree, followed by individuals with only a high school degree or GED. The strong low-skill labor demand shock in ND led to large-scale migration into extraction areas, driven by young single males with below average education (Wilson, 2016).

This in-migration of high-risk individuals like young males, individuals with criminal records, and increasing numbers of individuals living in group quarters or “man camps” increased local violent crime and property crime (Andrews and Deza, 2018; James and Smith, 2017). Bartik et al. (2016) estimate that local households are willing to pay up to -\$1,600 per year for increases in violent crime, noise, and other decreases in amenities associated with fracking. While the literature shows that fracking booms may increase crime, Street (2018) made creative use of multiple microdata sources to illustrate that crime amongst local residents (prior to the boom) of ND actually *decreased*. This suggests that increases in violent crime and property crime found by Andrews and Deza (2018) and James and Smith (2017) were driven solely by in-migrants.

2.3 Institutional Background

The Bakken Shale formation, a subset of the Three Forks Formation, is an oil and natural gas rich rock unit spanning northwestern North Dakota, northeastern Montana, and southern Canada (Figure 2.5). Although discovered in 1953, little oil was extracted from the Bakken Formation until 2007 due to the application of horizontal drilling and hydraulic fracturing (fracking), which dramatically increased the percent of original oil in place estimated to be technically recoverable. In 2008, the U.S. Geological Survey (USGS) estimated there to be between 3 to 4.3 billion barrels of technically recoverable oil within the Bakken Formation, which was 25 times higher than the 1995 USGS estimate. Changing from single-stage to multi-stage fracking gave companies more access to reservoir rock, a subsurface rock that contains petroleum. In 2013, the USGS increased its estimate of recoverable barrels of oil within the Three Forks Formation from 3.65 billion barrels of oil in 2008 to 7.4 in 2013, making it one of the largest oil discoveries in the history of the United States.[3] Therefore, the majority of all well drilling, a large job creator, occurred in northwestern ND.

The top oil producing counties in ND are Mountrail, Williams, McKenzie, and Dunn.[4] As of 2014, they accounted for about 89 percent of all ND oil production (see Figure 2.6 for map of ND counties). Adding Burke, Divide, and Stark counties accounts for 95 percent of all ND oil production. It would be both tempting and misguided to suggest that high county oil production is directly related to job growth. Although McKenzie and Mountrail are the top oil producing counties, both had populations less than 7,000 in 2008 and neither experienced the majority of oil boom job growth. Williston, ND in Williams County has been the heart of the oil patch. Between 2009 and 2013, the civilian labor force in Williams County increased more than threefold from 13,500 to 48,000 (Figure 2.7). Figure 2.8 displays a map of ND oil and gas drilling rig locations

[3]Source: 2013 USGS Release https://www.doi.gov/news/pressreleases/usgs-releases-new-oil-and-gas-assessment-for-bakken-and-three-forks-formations

[4]North Dakota Drilling and Production Statistics, Department of Mineral Resources

as of 2012, illustrating that over 90% of all rigs were within a 75 mile radius of Williston. Figure 2.10 is a NASA Earth Observatory night-lights image from 2012. It is abundantly clear that light pollution and natural gas flares are concentrated around Williston. This provides further support of defining the treatment area as a function of distance from Williston, ND.

2.4 Data

This paper utilizes three novel datasets. The data concerning high school graduation rates were obtained from the North Dakota Department of Public Instruction (NDDPI). These data are available from 2007-2008 to 2014-2015. To calculate high school graduation and dropout rates, students are placed in a cohort group from grade 9 and are tracked throughout their four years of high school. Adjustments are made to the cohort group if a student from the group drops out or transfers to another school or district. Students are given an exit code: graduate, dropout, deceased, transfer, or district transfer. The final numbers and rates are based on the ending cohort group in which only graduates and dropouts are included in the calculation. The data provide the number of students, graduation rate, and dropout rate of each school district. It might be expected for an economic shock to have differential effects on different races due to income and culture variation. As of the 2010 Census, 90% of North Dakotans were White American, 5.4% were Native American, 1.2% were African American, and 1% were Asian. However, differential effects by race were incalculable due to data restrictions and low population sizes. For privacy reasons, a rate is only reported by the NDDPI if the number of students within a race is greater than or equal to 10.

Although it would be ideal to have high school graduation rate data prior to 2007, the NDDPI did not collect such data. This cuts short the feasible pre-period of the event-study design. County level oil production data are available from the North Dakota Department of Mineral Resources Oil and Gas Division. As can be seen in Figure 2.9, oil production growth started in 2007 and escalated after 2010. My data limitations imply that the high school graduation rate event-study research design will compare a pre-period of "low" growth to a post-period of "high" growth. This suggests that results may understate the true effect of the oil boom on high school graduation rates.

The second source of data I use are Historical North Dakota University System (NDUS) Fall Enrollment Reports from 1998 to 2014. These administrative reports total the number of students in the NDUS by county-year-college cell. The NDUS includes 5 community colleges, 4 regional universities, and 2 research universities. The research institutions, North Dakota State University and the University of North Dakota, together have a total enrollment of around 29,000 students. Bismark State College and Minot State University both have total enrollments of around 4,000 students and are the 3rd and 4th largest universities in the State. Therefore, the NDUS largely represents the college choices of ND high schoolers if they decide to attend college in-state. One benefit of NDUS enrollment data over NDDPI post-graduation outcome data is that there is no issue of recall error on the part of school administrators so NDUS enrollment data should be less noisy.

The third data source I use are post-graduation outcomes obtained from the (NDDPI). Data is collected from every public and private school in all 53 ND counties. For each school district, the dataset provides the number of students, split by gender, with the respective post-graduation outcome. Data collection procedures may vary by school. In some schools, administrators determine the post-graduation outcomes in the summer after high school graduation. Given that North Dakota schools are small and social networks are tight, a guidance counselor can recall the outcome of each high school graduate. These outcomes are then reported to the NDDPI. The six options are employment, 2 year college, 4 year college, vocational technical school (henceforth, voc-tech), military, and unknown. The data spans 1998-1999 to 2013-2014. It is possible that an administrator may recall that a graduate attended college after graduation but may noisily decipher 2 year college from 4 year college. Therefore, I often aggregate 2 year and 4 year college enrollment into a total college enrollment rate. NDDPI post-graduation data may be noisier than NDUS enrollment data, but allow analysis by gender and make it feasible to study other post-graduation outcomes like employment or military enrollment. The NDDPI have the additional benefit of studying all students who attend college, not just those who attend school within the NDUS.

I use geolocated data from the ND Department of Mineral Resources Oil and Gas Division. The data include monthly snapshots of all active oil rigs in ND. Unfortunately, this data is only digitized back to 2012. Figure 2.1 displays a map of the change in average county unemployment before and after 2010, overlaid with public school districts and oil rig locations in 2012. The figure clearly shows that large unemployment reductions occurred in northwestern ND. Main oil producing counties experienced decreases in unemployment between 30% and 60%, from base rate unemployment between 2.1% to 4%. Thus, the oil boom improved the economic conditions of a geographic region that already had tight labor markets.

2.5 Empirical Strategy

To study the effects of the oil boom on high school graduation rates and post-graduation outcomes, I use an event-study specification paired with difference in difference (DD) estimates. The design compares outcomes in schools within core-oil counties relative to non-oil counties before and after the oil boom. Economic theory suggests that schools in the proximity of the oil boom centroid are those most impacted by the boom. Commute times and psychic costs increase as distance from the oil boom increases. Individuals further from the boom must leave social networks and are less likely to have social connections in the oil drilling area. This is particularly salient in northwest ND as housing became expensive in two ways. One, the oil boom caused housing prices and rent to skyrocket with some news sources comparing rent to that found in New York City.[5] Second, the cheaper alternatives of living out of a Recreational Vehicle (RV) or in a "man camp" have non-monetary costs associated with limited amenities and overcrowding.

Core-oil counties are defined by the state of North Dakota (Center, 2017) and are seen in Figure 2.6. Figures 2.2 and 2.3 illustrate the rapid divergence between wages and employment levels in core-oil verus non-oil producing counties. Figure 2.4 provides clear evidence that employment and wages also increased in female dominated sectors like leisure and hospitality. For high school

[5] http://www.nydailynews.com/life-style/real-estate/average-rent-williston-n-tops-costs-nyc-article-1.1617187

graduation rates, I define “Post" oil boom as 2011 and later. I determined this using yearly oil production data and limited leeway due to lack of data before the boom. Between 2007 and 2010, North Dakota oil production increased to 100 million barrels of oil per year. Between 2011 and 2014, oil production jumped to nearly 400 million barrels per year. Using 2011 as the cutoff provides three years of data before the boom and five years of data after the boom. Figure 2.3 displays average monthly employment levels for core-oil and non-oil counties. Core oil and non-oil counties share remarkably similar trends up to 2007, when employment in oil counties starts to increase. Employment in oil counties increases steadily until 2010, after which employment in oil counties skyrockets. As stated in the data section, the NDDPI did not collect high school graduation rate data prior to 2007. Due to this restriction on high school graduation rate data, the research design will compare educational outcomes in periods of high wage and employment growth to periods with tamer wage and employment growth. To the extent that high school graduation rates started to change prior to 2010, the DD estimate will understate the true extent of the effect of the oil boom on educational outcomes.

NDUS enrollment data and NDDPI post-graduation outcome data are available back to 1998 and the respective oil boom starting year is defined as 2009. I estimate specification (2.1), a linear fractional response model using an event-study research design. I estimate the model separately for each of the six post-graduation plan outcomes. Y_{ct} is the fraction of students in county c in year t who report the respective post-graduation outcome. “Core” is a binary variable equal to one for core-oil counties. λ_t denotes year fixed effects to account for statewide yearly shocks. County fixed effects, ϕ_c, absorb time invariant unobserved heterogeneity of county specific factors. I cluster standard errors at a county level to allow correlation of the error term within a county over time (Bertrand et al., 2004).

$$Y_{ct} = \phi_c + \lambda_t + \sum_{y=-11}^{-2} \delta_y Core_c 1(t - T^* = y) + \sum_{y=0}^{5} \gamma_y Core_c 1(t - T^* = y) + e_{ct} \tag{2.1}$$

2.6 Results

2.6.1 Effects on High School Graduation Rates

The work of Black et al. (2005) and Cascio and Narayan (2015) both suggest that natural resource booms, which heavily rely on low-skill labor, decrease high school graduation rates. Therefore, it is surprising that raw trends in Figure 2.11 illustrate no visible decrease in high school graduation rates for schools within core-oil counties. The figures show that core-oil county graduation rates follow similar trends to non-oil counties for the years in which core-oil county wages increase the most relative to non-oil county wages. This holds true for both males and females. The most notable drop in high school graduation rates occurs with the onset of The Great Recession in 2009. To formally test whether the oil boom impacted graduation rates, Figure 2.12 presents event-study estimates. Event study estimates provide no evidence that the oil boom decreased graduation rates in core-oil counties for males or females. These results contrast with Cascio and Narayan (2015), suggesting that impacts of shale oil booms on high school attainment decisions are not uniform throughout the United States.

Although the oil boom increased lower skilled employment and wages, many of these jobs, especially oil field jobs, require a high school diploma or GED as well as a minimum age requirement (typically 18 to 21).[6] Transportation, another booming sector, often requires a worker to have a Commercial Driver's License (CDL). North Dakota does not issue Class A, B, or C licenses to those under age 18 except for agricultural purposes.[7] North Dakota also has a compulsory attendance law which requires a student to stay in school until his or her 16th birthday.[8] Though higher wages exist, high school students may face high barriers to entry that only disappear upon graduation. Unlike the Appalachian coal boom of the 1970s or shale oil booms in other areas of the United States, high school students in ND may not change high school graduation decisions, but may alter post-graduation decisions.

[6] http://www.jobsnd.com/sites/default/files/Oilfield%20Employment%20Guide.pdf

[7] ND DMV: http://www.dmv.org/nd-north-dakota/apply-cdl.php#NorthDakota-Legal-Age-Limits

[8] http://www.dpi.state.nd.us/health/factsheets/truancy.pdf

2.6.2 Effects on NDUS Enrollment Rates

Administrative data from NDUS fall enrollment reports provide the number of students attending each NDUS college by county of residence. These reports, combined with county level high school graduation data, can be used to create county level in-state college enrollment rates. Total college enrollment by county is both a stock of previous enrollment (rising freshman, sophomores, and juniors) and a flow of incoming freshman. Therefore, I calculate a college enrollment rate of county c in year t by taking current county college enrollment and dividing by previous years of county high school graduates (equation 2.2).

$$CollegeRate_{ct} = \frac{enrollment_{ct}}{hsgrads_{c,t-3} + hsgrads_{c,t-2} + hsgrads_{c,t-1} + hsgrads_{c,t}} \tag{2.2}$$

I also calculate enrollment rates separately for both 2 year and 4 year colleges in North Dakota, as it may be interesting to study whether oil booms have any impact on more traditional students in 4 year colleges. Table 2.1 presents summary statistics of enrollment rates by type of college. The sample averages suggest that 4 year enrollment rates remained constant in non-oil counties but decreased 11 percentage points (22%) in core-oil counties after the oil boom. While regional and research university rates remained constant in non-oil counties, the rates decreased 7 and 5 percentage points (respectively) in core-oil counties after the boom. The summary statistics provide no evidence of 2 year enrollment rates being impacted. Raw college enrollment rate trends in Figure 2.13 show that college enrollment in core-oil and non-core counties exhibited similar trends prior to the boom, providing support for the parallel trends assumption inherent to a DD research design. However, after the onset of the oil boom, college enrollment rates in core-oil counties sharply diverged.

Event-study estimates of college enrollment rates are presented in Figure 2.14. Event-study estimates suggest that the oil boom had a significant and prolonged negative effect on NDUS college enrollment rates in core-oil counties. The respective DD estimates in Table 2.2 suggest that total college enrollment rates decreased 11 percentage points (15%). As noted in Cascio and

Narayan (2015), shale oil booms are male and low-skill biased labor shocks. We might expect that community college students might be more likely to be on the margin of joining the labor force than 4 year college students. Surprisingly, Figure 2.15 suggests that the oil boom reduced 4 year college enrollment rates but had negligible effects on community college enrollment rates. DD estimates in Table 2.2 provide strong evidence that 4 year college enrollment rates decreased 12 percentage points (23%) in core-oil counties. The NDUS has two types of 4 year colleges: two research universities and four regional state colleges. If research universities attract higher skilled students, we might expect less research university students to be on the margin of forgoing college to enter the labor force. Figure 2.16 provides evidence that enrollment rates decreased for both regional colleges and research universities (21% and 25% decreases as found in Table 2.2).

A potential concern is that the oil boom may have caused in-migration into core-oil counties. High school graduates of mobile parents who work in oil or oil-related jobs may be less likely to attend college. These in-migrant high school students would contribute to the denominator of the enrollment rate calculated in Figure 2.2, artificially driving a decrease in college enrollment rates. While Figure 2.A1 provides some evidence that core-oil graduate numbers rebounded after 2007, overall trends in high school graduate numbers between core-oil and non-core counties appear similar throughout the time period. To mitigate the concern of in-migration driving results, I present event-study estimates in Figure 2.17 where the outcome is log number of students from each county. In these specifications, in-migration will place a positive bias on enrollment numbers if any in-migrant high school graduates attend a NDUS college. Nevertheless, event-study estimates in Figure 2.17 provide strong evidence that the oil boom reduced NDUS student enrollment for both regional colleges and research universities. None of the event-studies suggest any issue of pre-trends in enrollment outcomes. The respective DD estimates in Table 2.3 provide similar estimates as above: a 19% decrease in 4 year college enrollment with no evidence of decreases in 2 year college enrollment.

2.6.3 Effects on NDDPI Post-Graduation Outcomes

NDUS enrollment reports clearly show that the oil boom impacted college enrollment rates. I supplement the NDUS enrollment analysis with NDDPI post-graduation data, which may be noisier but allow us to study effects by gender and extend analysis to other outcomes. Table 2.4 displays post-graduation outcome rates, by gender, for core-oil and non-oil counties before and after the boom. Summary statistics and the following analysis are limited to public high schools in ND. Prior to the boom post-graduation outcomes were similar in core-oil and non-oil counties, though individuals in core-oil counties were more likely to attend 2 year colleges and less likely to attend 4 year colleges. It is clear that schools in non-oil counties exhibit rather constant post-graduation plan choices, aside from some switching between 2 year college, 4 year college, and voc-tech. The employment rate in non-oil counties remained essentially the same before and after the boom (.142 versus .141). However, schools in core-oil counties exhibit large changes in post-graduation outcomes. The fraction of students seeking employment upon graduation increased from .16 to .23, while the fraction enrolling in a four year college decreased from .42 to .33. Though oil booms are generally associated with low-skill male labor, it is clear that *both* male and female post-graduation outcomes changed. Previous literature focuses on male outcomes. Black et al. (2005) study male high school graduation rates while Cascio and Narayan (2015) implement a triple-difference specification that studies the male-female gap in high school dropout rates. The raw means in Table 2.4 show that female employment rates in core-oil counties increased from .12 before the oil boom to .19 after. Meanwhile, 4 year college enrollment rates dropped 12 percentage points. These summary statistics imply that females can also be significantly impacted by shale oil booms. Appendix Figures A.1 through A.7 present raw trends of post-graduation outcomes over time. Notably, Figure 2.A2 displays a sharp decrease in college enrollment rates in core-oil counties that coincides with oil boom. Figure 2.A3 shows a similar increase in employment rates while Figure 2.A7 suggests that military enrollment rates decreased as the oil boom expanded. While shale oil booms are often thought to be male-biased, Figure 2.A5 suggests that both male *and* female 4 year college enrollment rates decreased after the boom. Though sample averages are imprecise, Figure 2.A7 provides evidence that male military enrollment rates in core-oil counties decreased after the boom while non-core military enrollment rates remained steady.

Figure 2.18 presents event study estimates of total college enrollment rates (the sum of 2 and 4 year college enrollment rates). There is no evidence of trends prior to the oil boom, which supports the parallel trends assumption of a DD specification. Event-study estimates provide strong evidence that total college enrollment rates decreased in core-oil counties after the oil boom for both males and females. The novel result here is that female college enrollment is also impacted by the oil boom. It is reassuring that both NDUS and NDDPI event-study estimates show a decrease in college enrollment rates that are strongest around 2011 (near the peak of the oil boom). Figure 2.19 suggests that employment rates in core-oil counties increased after the oil boom, with less precise estimates suggesting that employment rates increased for both males and females. It may be interesting to study which students are on the margin. Interestingly, Figure 2.21 and Figure 2.20 suggest that 4 year college enrollment rates decreased more than 2 year college enrollment rates. Consistent with previous work on natural resource booms, decreases in 4 year college enrollment rates are driven by males. Figure 2.22 provides evidence that the oil boom had large negative impacts, relative to the mean, on male military enrollment rates. This is consistent with a shale oil boom being a large labor market shock to prime age male employment.

2.7 Conclusion

The ND oil boom has drastically impacted northwestern counties of the state. As of 2014, unemployment rates of the top four oil producing counties averaged 1.4%. The oil boom significantly increased both employment levels and wages. The civilian labor force in Williams County increased threefold between 2008 and 2013, with doubling wages and low unemployment. Employment data form the QCEW shows that there was strong employment growth in female-heavy industries as well as male industries. I provide strong evidence that the tightening of labor markets altered educational attainment decisions of high school seniors in North

Dakota while high school graduation rates remained unchanged.

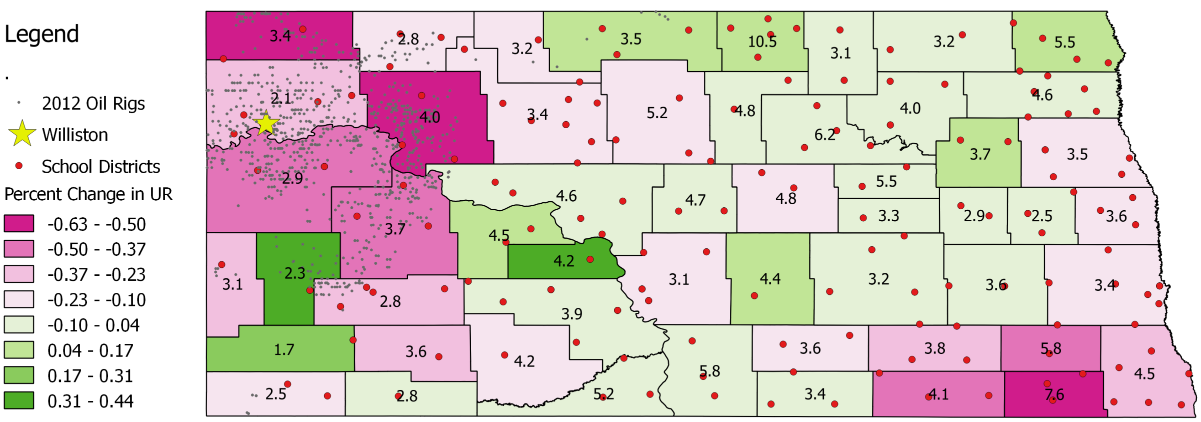
I use an event-study design paired with a difference in difference (DD) approach to examine the effects of the oil boom on post-graduation outcomes for both males and females. Using administrative data from allows the NDDPI for a finer analysis than is possible with survey data in a sparsely population region like rural North Dakota. The DD research design compares educational outcomes for schools within core-oil and non-core oil counties before and after the oil boom. Event-study analyses and DD estimates provide no evidence that the oil boom had any negative effect on core-oil high school graduation rates. These results differ from Cascio and Narayan (2015), suggesting that nation-wide analyses may mask interesting heterogeneity by region. However, the decision to attain a high school degree is only one margin on which a student can move, suggesting that post-graduation decisions are an interesting margin to analyze.

Event-study figures illustrate that there were no aggregate pre-trends in college enrollment rates of core-oil counties prior to the oil boom. The event-study analyses provide strong evidence that the oil boom had large and prolonged negative impacts on college enrollment rates in core-oil counties. Respective DD estimates strongly suggest that 4 year college enrollment rates decreased 12 percentage points (23%) while 2 year enrollment rates were not impacted. Notably, even enrollment rates at the higher-skill research universities decreased 25% in core-oil counties. This provides clear evidence that even potential high-skill students are on the margin between a 4 year degree and an oil-related job. To mitigate concerns of in-migration bias, I estimate similar models with logged student enrollment. In-migration would place a positive bias (making it less likely to find a negative effect on enrollment), but estimates are remarkably stable and suggest that student enrollment numbers in 4 year colleges decreased 19%.

Event-study analyses from administrative high school data (NDDPI) suggest that high school seniors substituted away from college enrollment and became more likely to directly enter the labor force. Separate analysis by gender suggests that both male *female* employment rates increased in core-oil counties after the boom. Similarly, college enrollment rates also decreased for both genders. These novel results provide clear evidence that females can also be impacted by shale oil boom. While shale oil booms in certain regions of the country may be dominated by oil-related employment growth, the boom in North Dakota was also associated with growth in non-oil jobs. Lastly, I find evidence that male military enrollment rates decreased in core-oil counties after the boom. This is unsurprising give that both oil-related employers and the military recruit prime-age males.

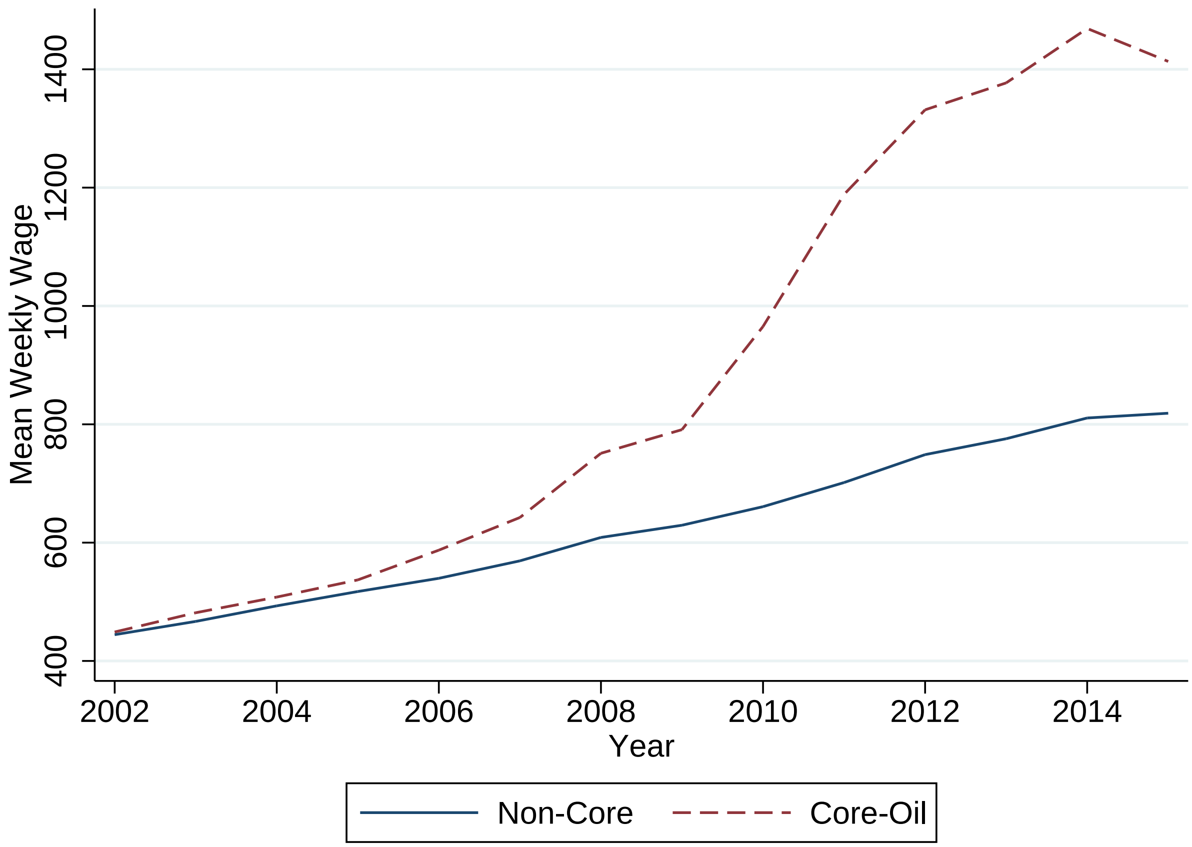
This is the first paper to analyze the impact of the ND oil boom on post-graduate educational attainment. The majority of literature studying natural resource booms and educational attainment focuses on high school graduation rates. Although high school gradation rates are an important area of research, high school graduation rates in ND are high and steady throughout the time period (around 87%). The insensitivity of high school graduation rates to job creation and wage shocks does not suggest that higher level educational attainment decisions are unaffected. This paper has policy implications for any region subject to natural resource booms. This analysis is especially relevant to rural areas of Texas, Pennsylvania, or other states undergoing fracking booms. These results are also relevant to North Dakota itself. Oil production in ND has curtailed since 2015. Low world crude oil prices decreased below many oil rig break-even prices and overall job growth stagnated. If future world crude prices increase significantly above $50 per barrel, North Dakota oil activity will boom again and high school seniors will face similar incentives to those studied in this paper. Regions that experience reductions in college enrollment rates in lieu of employment may benefit during the boom, but will be left with a surplus of low-skill unemployed workers when the boom goes bust.

Figure 2.1: Percent Change in County Unemployment Rate



Notes: The yellow star denotes Williston, ND. All gray dots denote oil rigs as of a 2012 snapshot. Red dots denote all public school districts. The color of the county border denotes the percent change in the county unemployment rate with 2008-2009 as the pre-period and 2010-2015 as the post period. The number reported within the county border denotes the county's pre-period average unemployment rate.

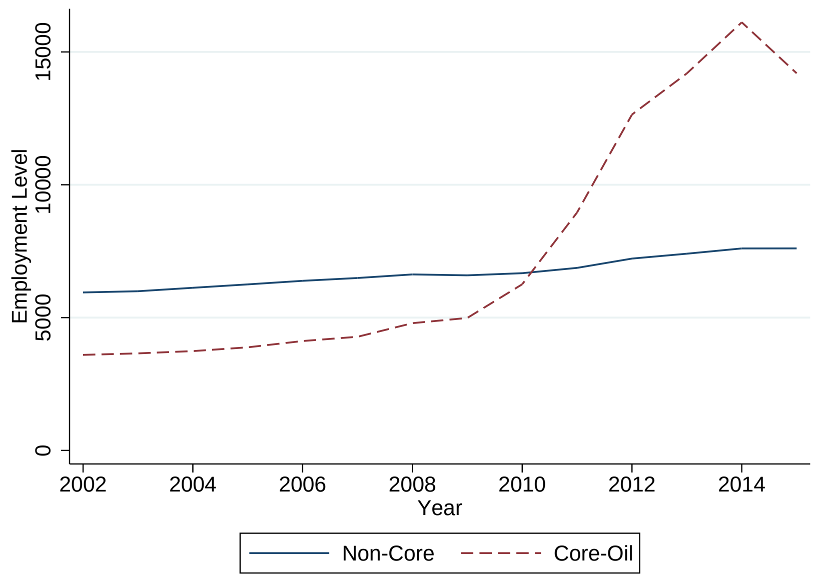
Figure 2.2: North Dakota Average Weekly Wages



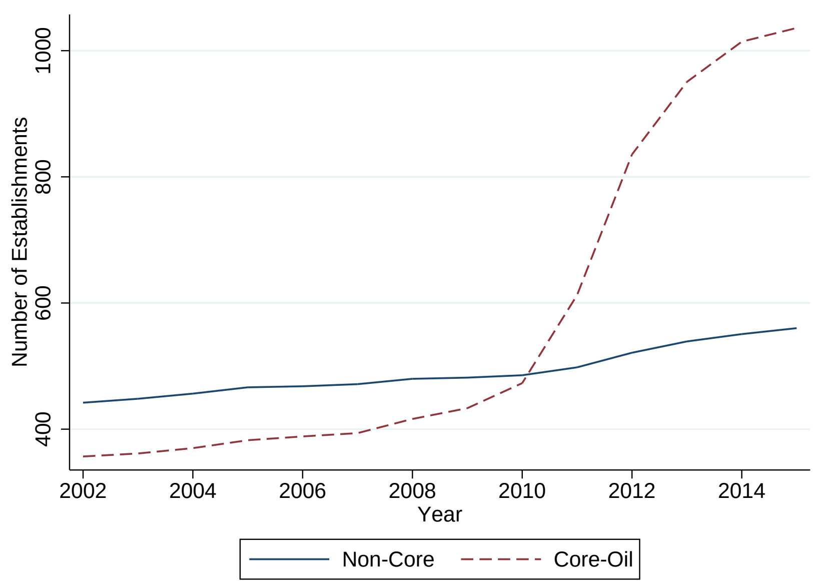
Notes: Core Oil counties are defined by the state of North Dakota (Center, 2017). The 4 core oil counties are Mountrail, Williams, McKenzie, and Dunn. Employment and wage data from the QCEW.

Figure 2.3: QCEW Employment Level and Establishment Count

(a) Average County Employment Level



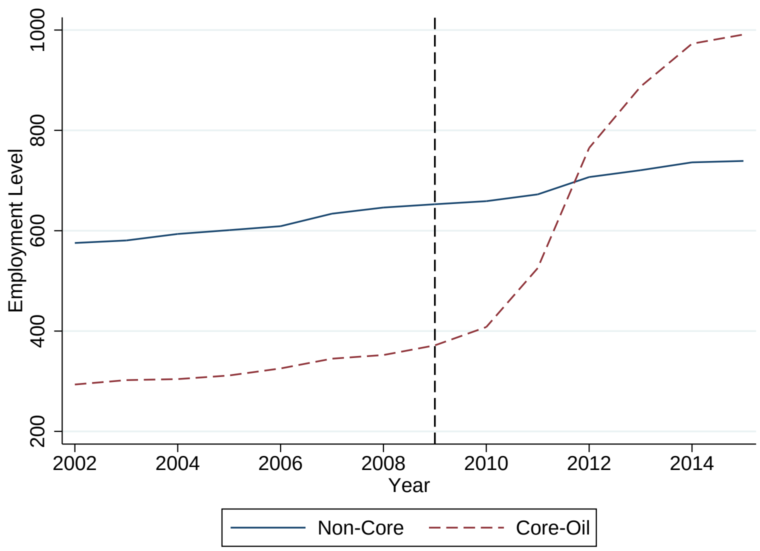
(b) Average Number of Establishments per County



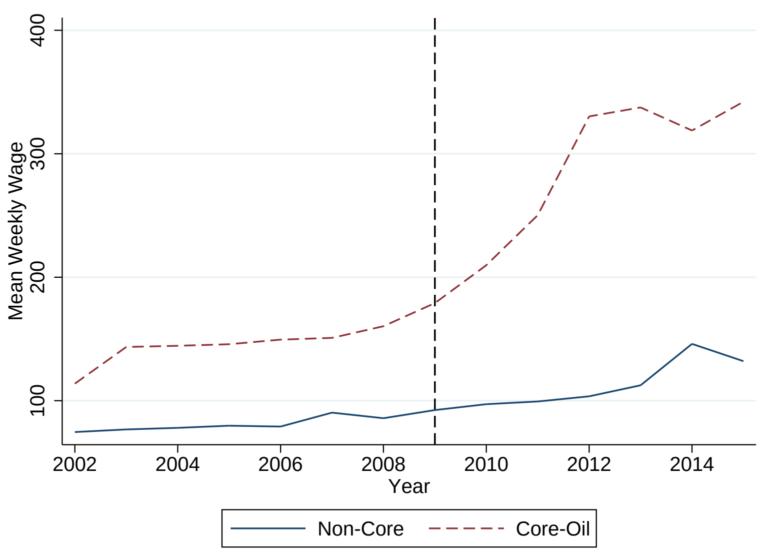
Notes: Core Oil counties are defined by the state of North Dakota (Center, 2017). The 4 core oil counties are Mountrail, Williams, McKenzie, and Dunn. Employment and wage data are from the QCEW.

Figure 2.4: Leisure & Hospitality Employment Level and Wages

(a) Leisure & Hospitality Employment Level

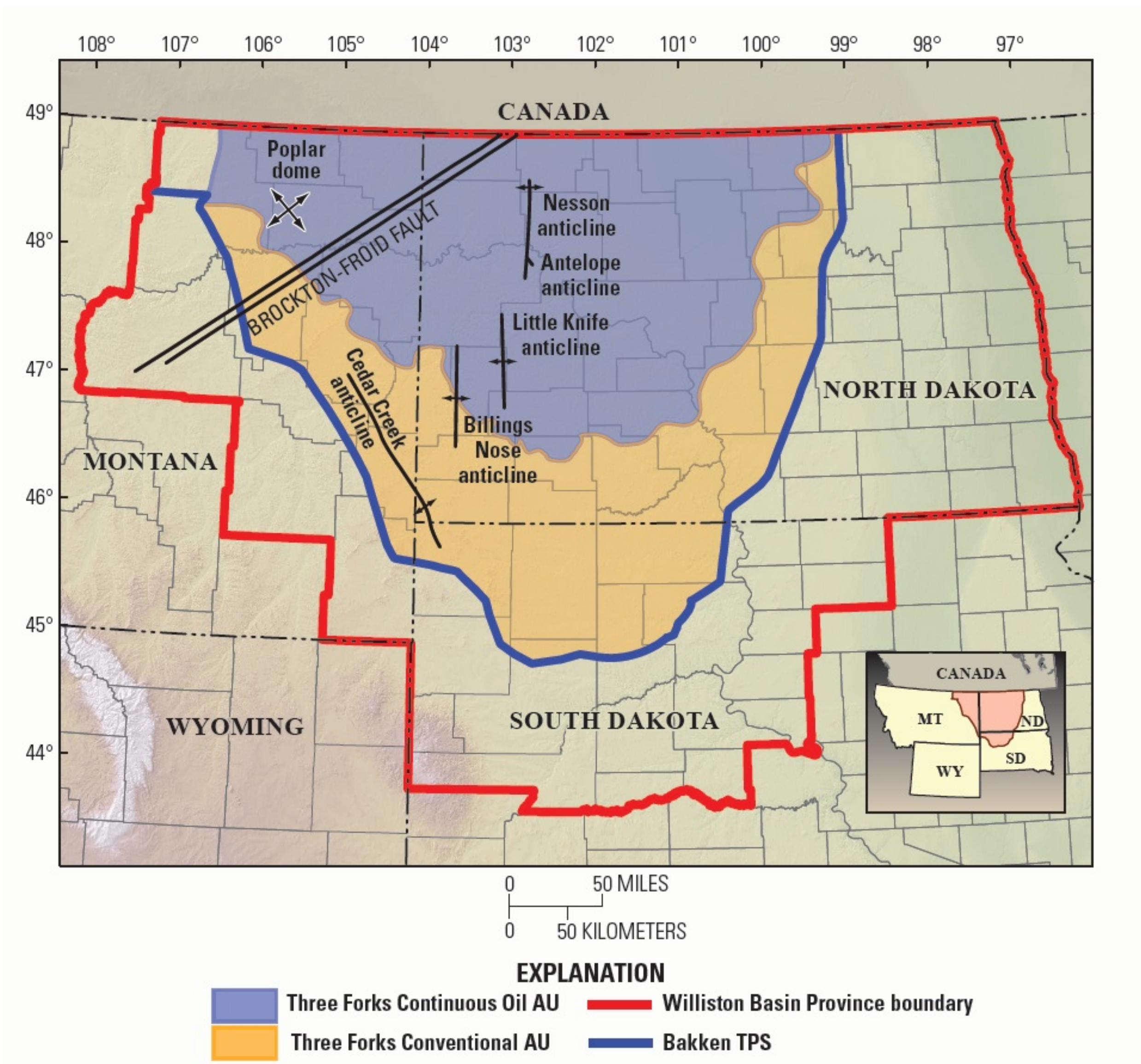


(b) Leisure & Hospitality Mean Wages



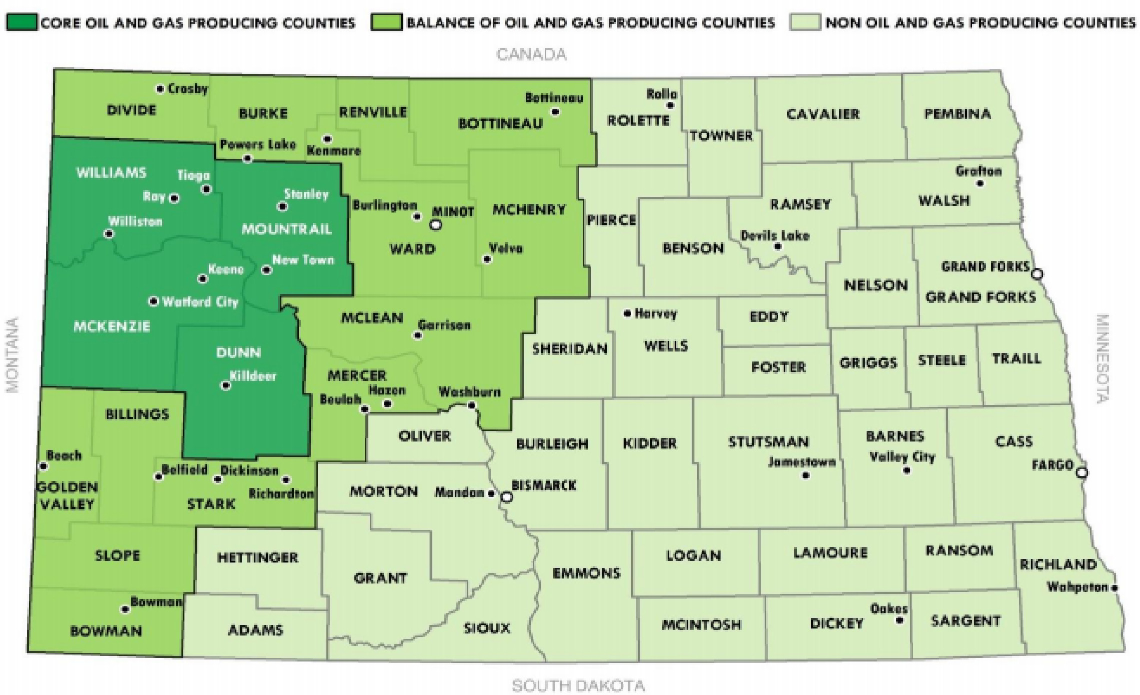
Notes: Core Oil counties are defined by the state of North Dakota (Center, 2017). The 4 core oil counties are Mountrail, Williams, McKenzie, and Dunn. Employment and wage data are from the QCEW.

Figure 2.5: Bakken Formation



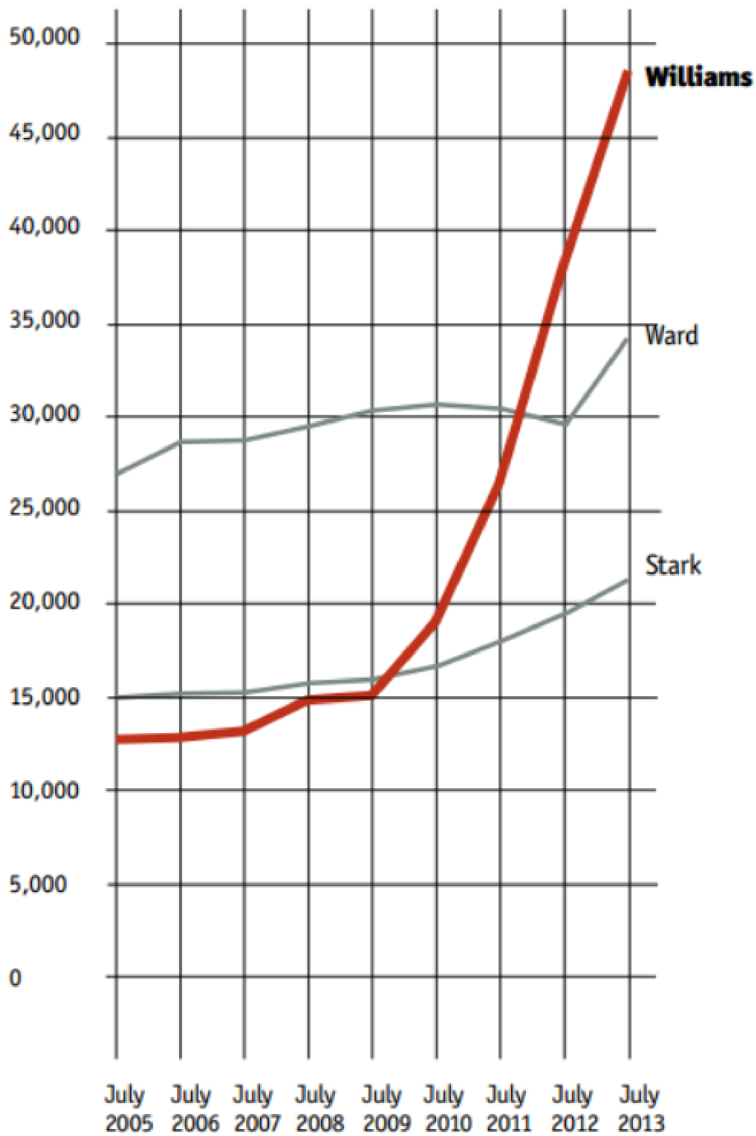
Source: U.S. Geological Survey (USGS)

Figure 2.6: North Dakota Counties



Source: Labor Market Information Center; Job Service North Dakota

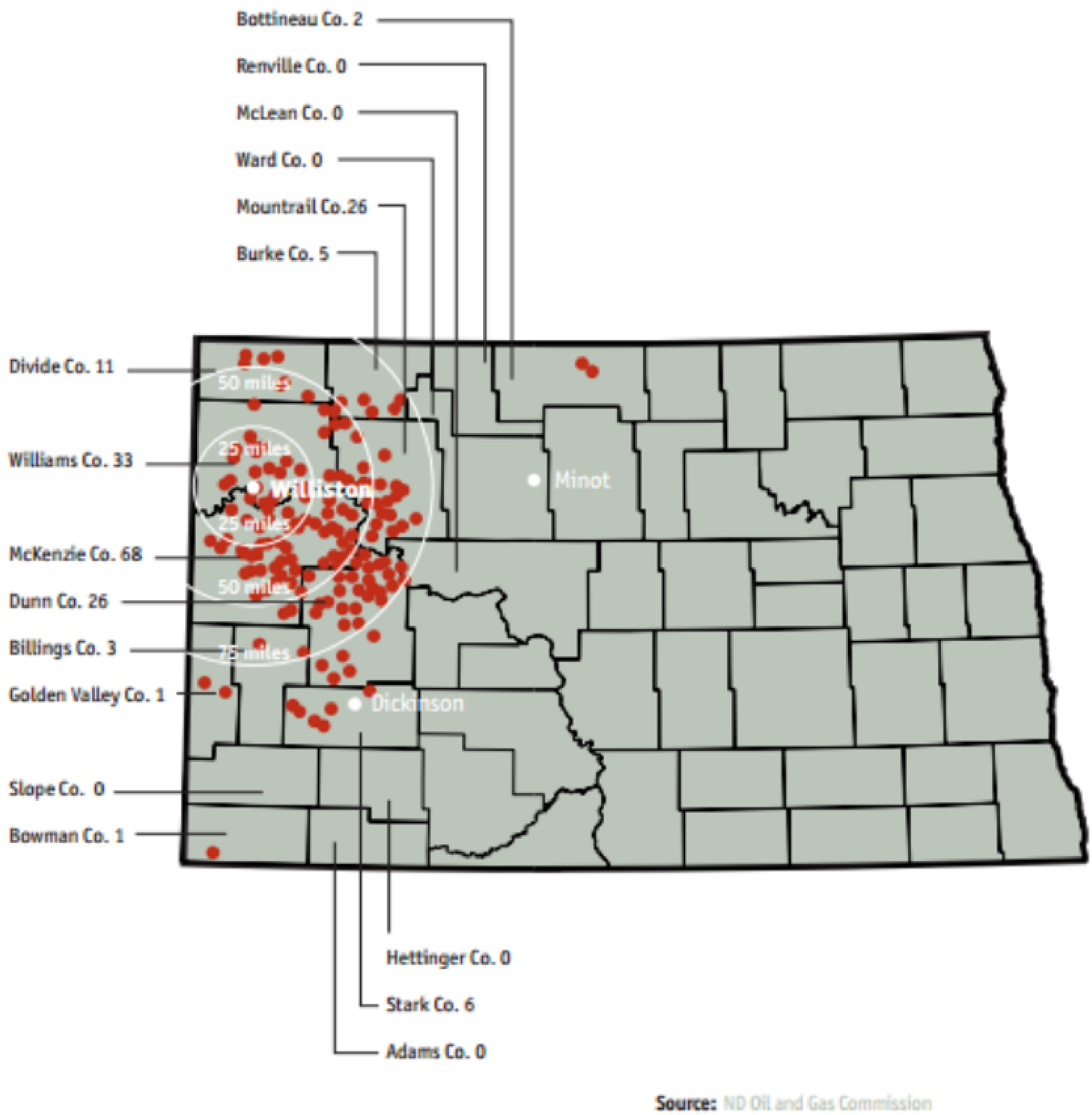
Figure 2.7: Civilian Labor Force by County



The civilian labor force is a single count by place of residence. The number includes those over the age of 16 who are employed or actively seeking employment.

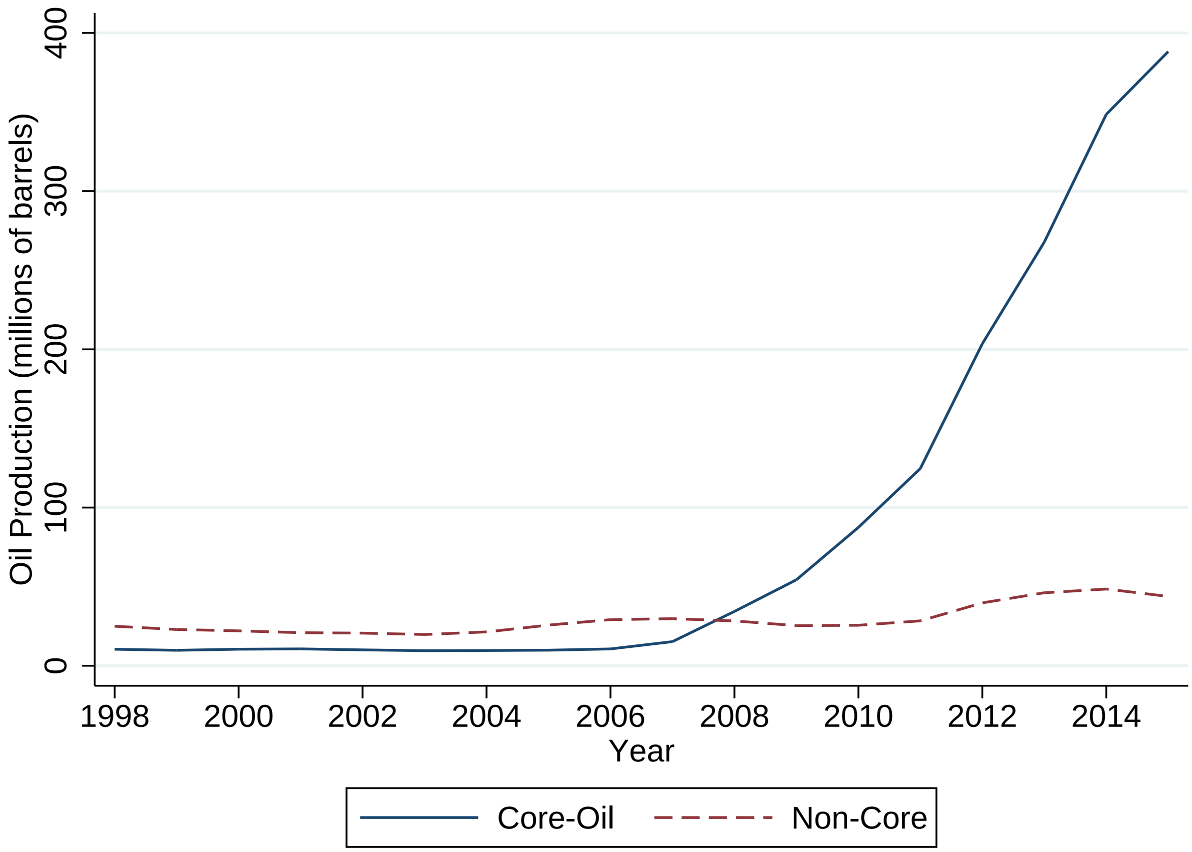
Source: Williston Impact Statement 2014. Williams, Ward, and Stark are the three most populated counties impacted by the oil boom.

Figure 2.8: ND Oil and Gas Drilling Rigs



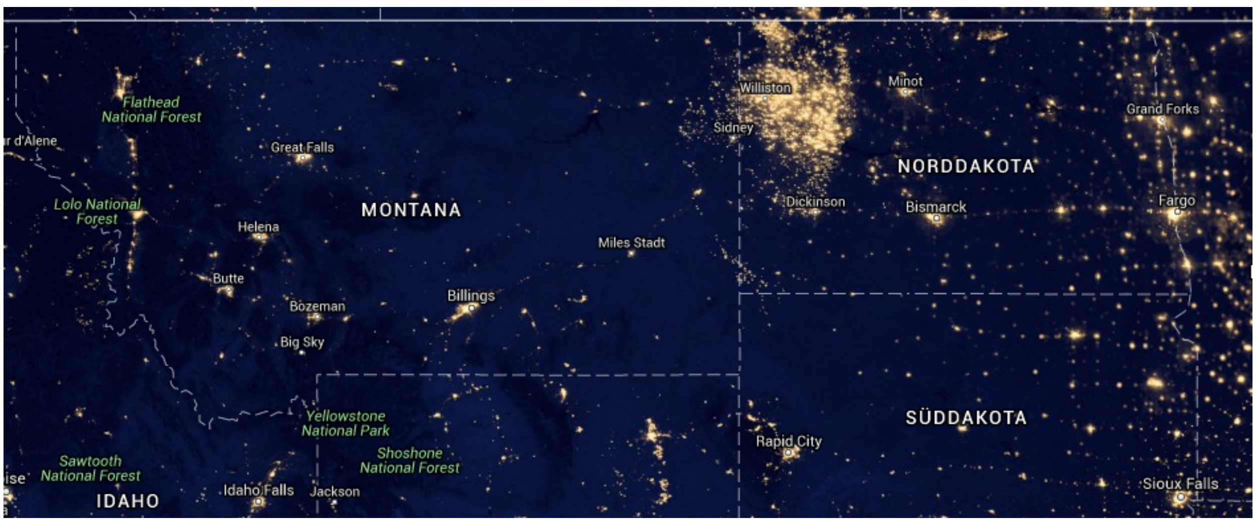
Source: Williston Impact Statement 2013

Figure 2.9: ND Oil Production



Source: ND Department of Mineral Resources (ND DMR)

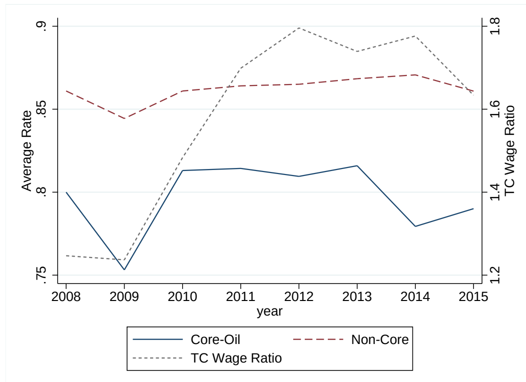
Figure 2.10: NASA Earth Observatory Night-Lights Imagery



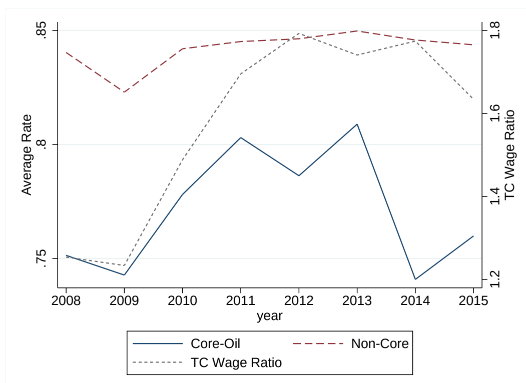
Source: NASA Earth Observatory; 2012

Figure 2.11: Graduation Rate Trends

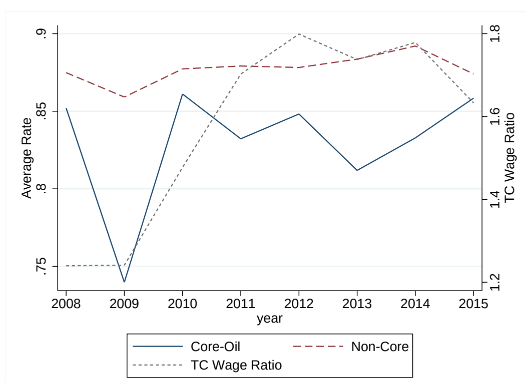
(a) Total Graduation Rate



(b) Male Graduation Rate



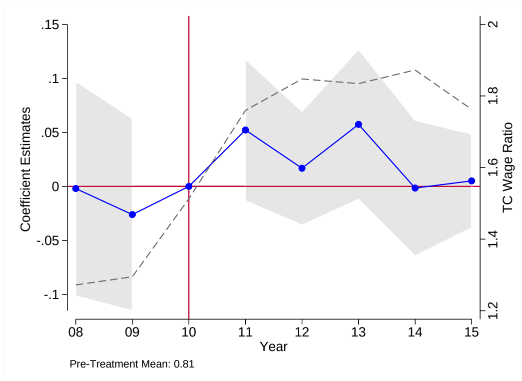
(c) Female Graduation Rate



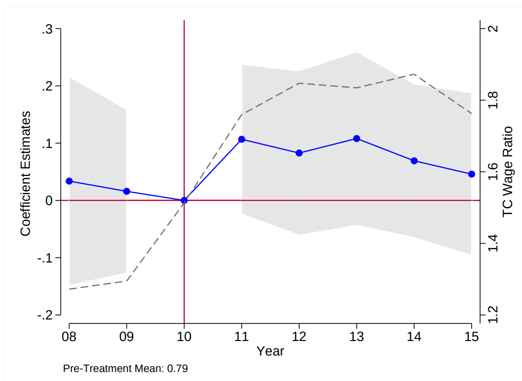
Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties.

Figure 2.12: Graduation Rate Event-Studies

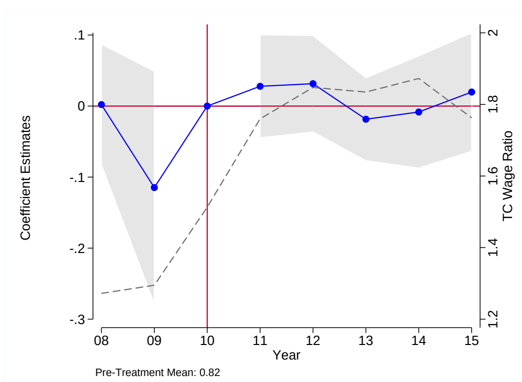
(a) Event-Study: Total Graduation Rate



(b) Event-Study: Male Graduation Rate

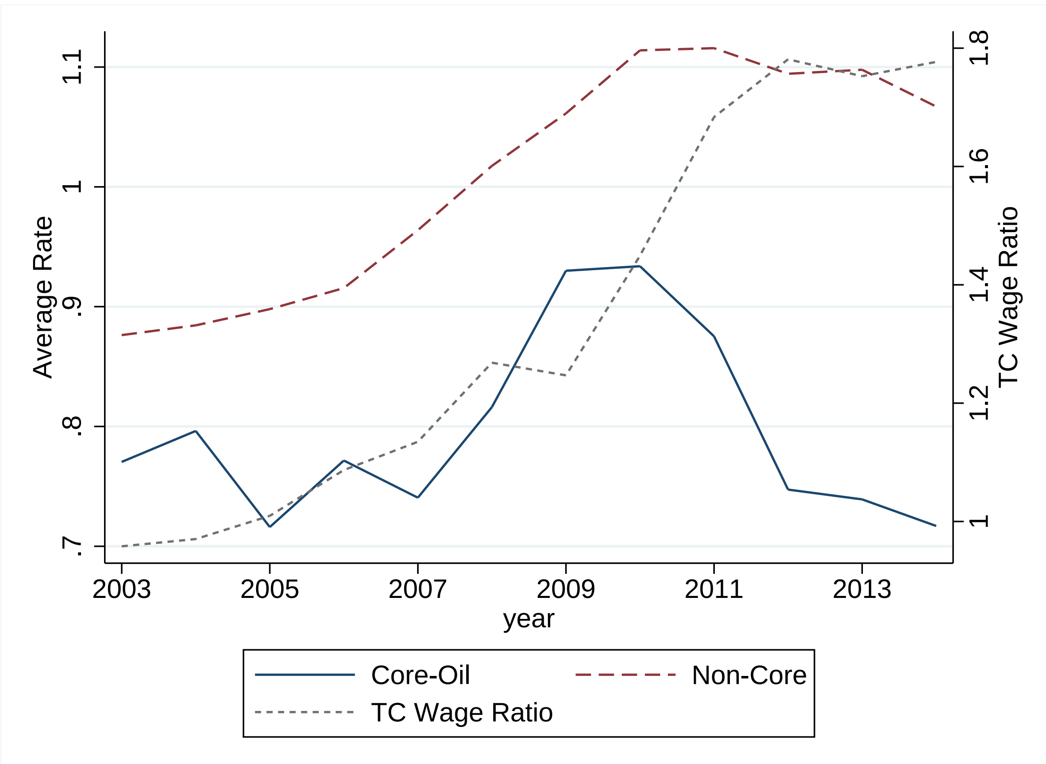


(c) Event-Study: Female Graduation Rate



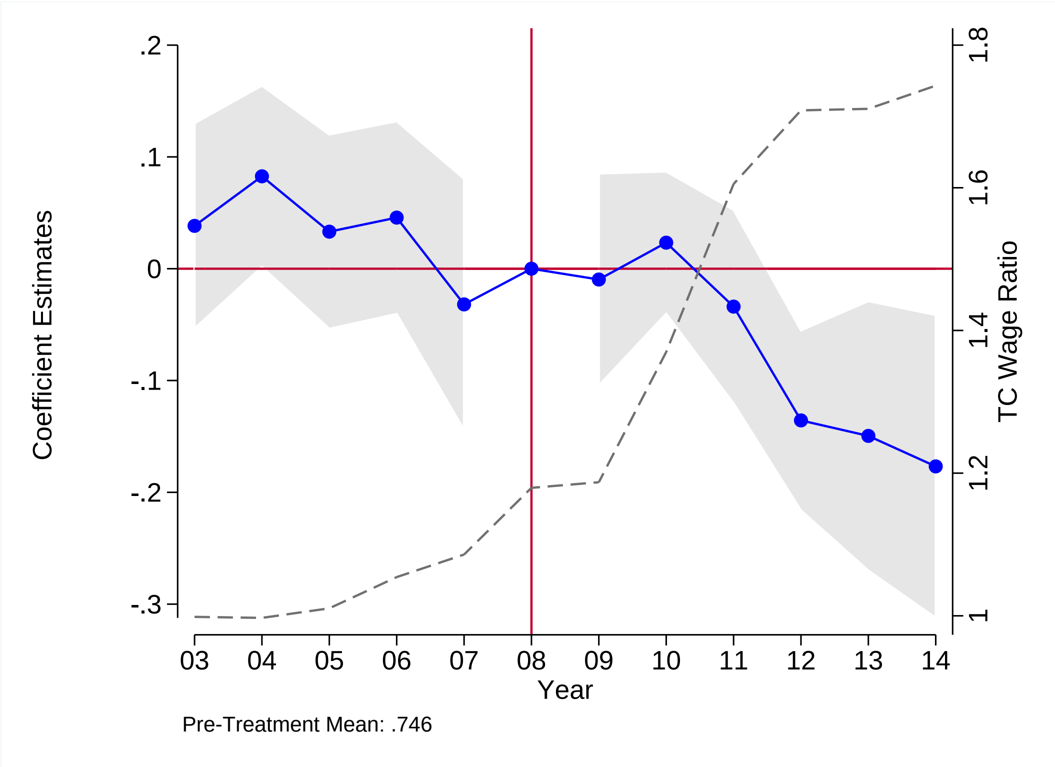
Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties.

Figure 2.13: NDUS College Enrollment Rate Trends



Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties.

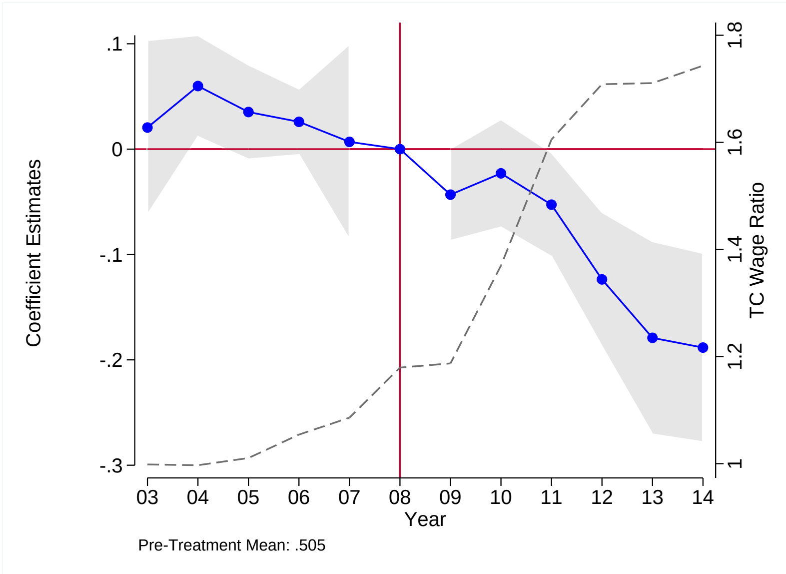
Figure 2.14: NDUS College Enrollment Rate Event-Study



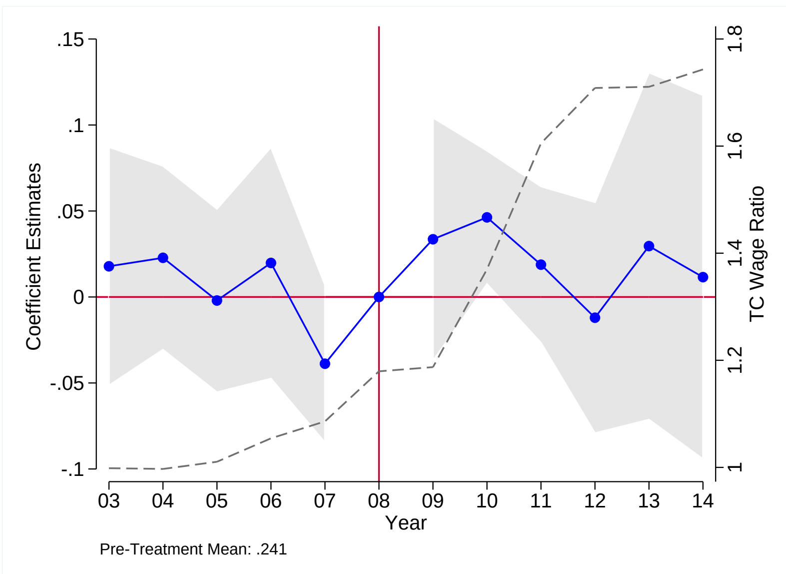
Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties.

Figure 2.15: Event-Studies of 4 Year versus 2 Year College

(a) NDUS 4 Year College Enrollment Rate Event-Study



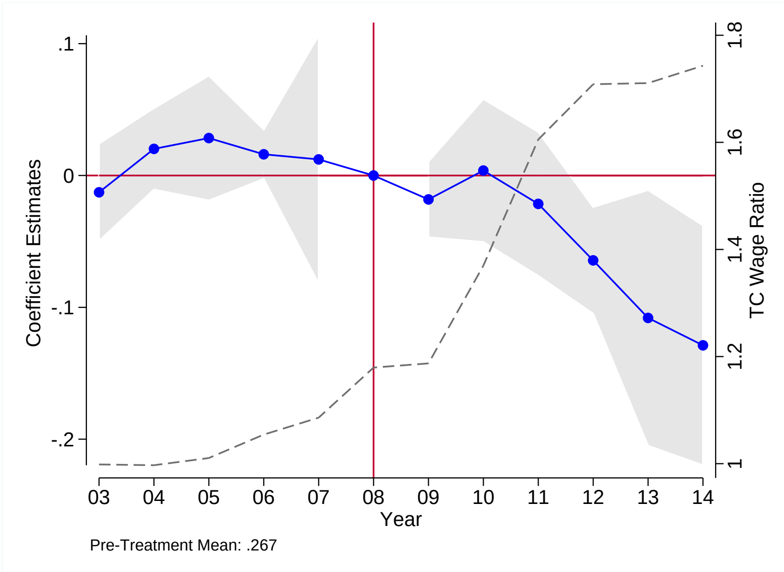
(b) NDUS 2 Year College Enrollment Rate Event-Study



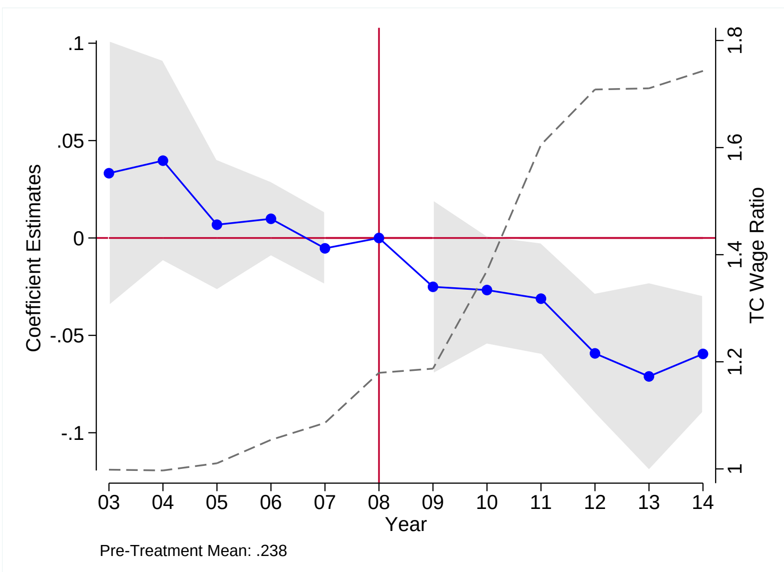
Notes: Figures present event-study estimates from models that include county and year fixed effects. The dependent variable is the calculated 4 year (and 2 year) college enrollment rate of county *c* in year *t*. Standard errors are clustered by county, with 95% confidence intervals provided. TC Wage Ratio is the ratio of mean weekly wages in core oil counties relative to non-oil counties.

Figure 2.16: Event-Studies by Type of 4 Year College

(a) NDUS Regional College Enrollment Rate Event-Study



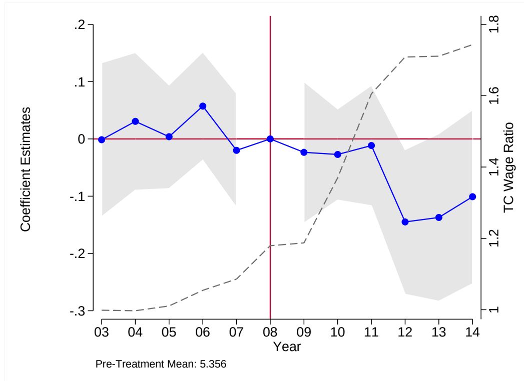
(b) NDUS Research College Enrollment Rate Event-Study



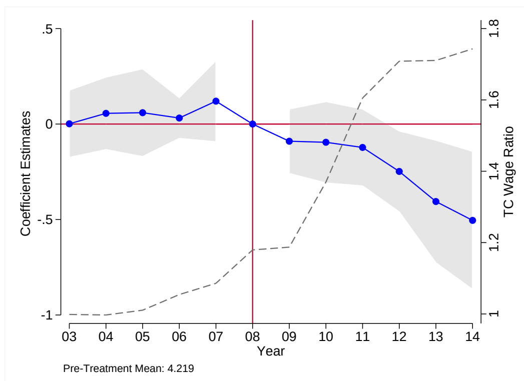
Notes: Figures present event-study estimates from models that include county and year fixed effects. The dependent variable is the calculated regional (and research) college enrollment rate of county *c* in year *t*. Standard errors are clustered by county, with 95% confidence intervals provided. TC Wage Ratio is the ratio of mean weekly wages in core oil counties relative to non-oil counties.

Figure 2.17: Event-Studies of Log Number of Students Enrolled

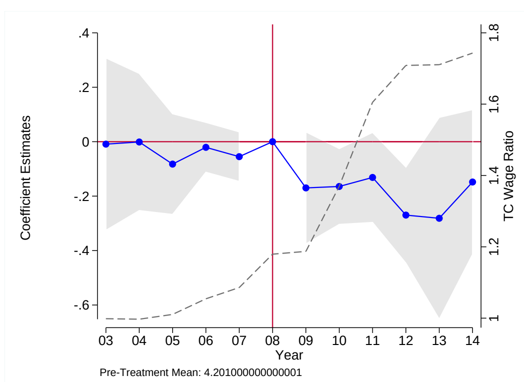
(a) Log(NDUS Students)



(b) Log(NDUS Regional College Students)



(c) Log(NDUS Research College Students)



Notes: Figures present event-study estimates from models that include county and year fixed effects. The dependent variable is the natural log of the number of students enrolled in an NDUS college in county *c* in year *t*. Standard errors are clustered by county, with 95% confidence intervals provided. TC Wage Ratio is the ratio of mean weekly wages in core oil counties relative to non-oil counties.

Figure 2.18: Event Study Estimates of Any College Enrollment

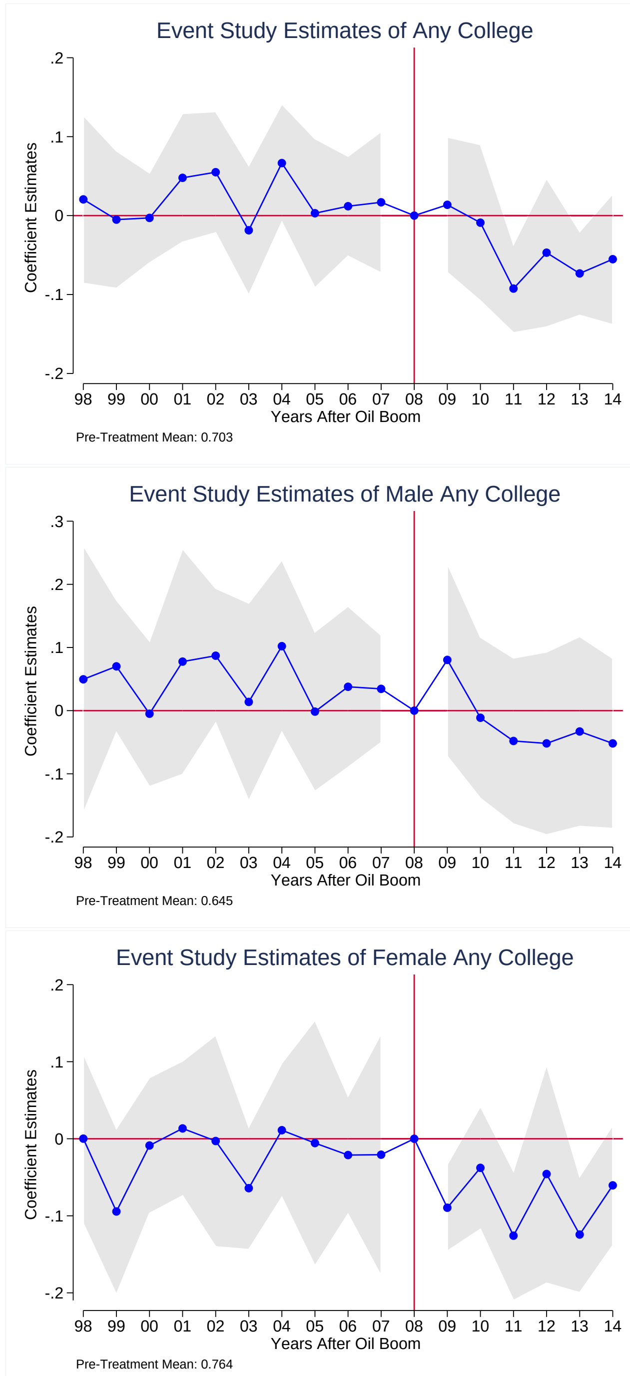


Figure 2.19: Event Study Estimates of Employment

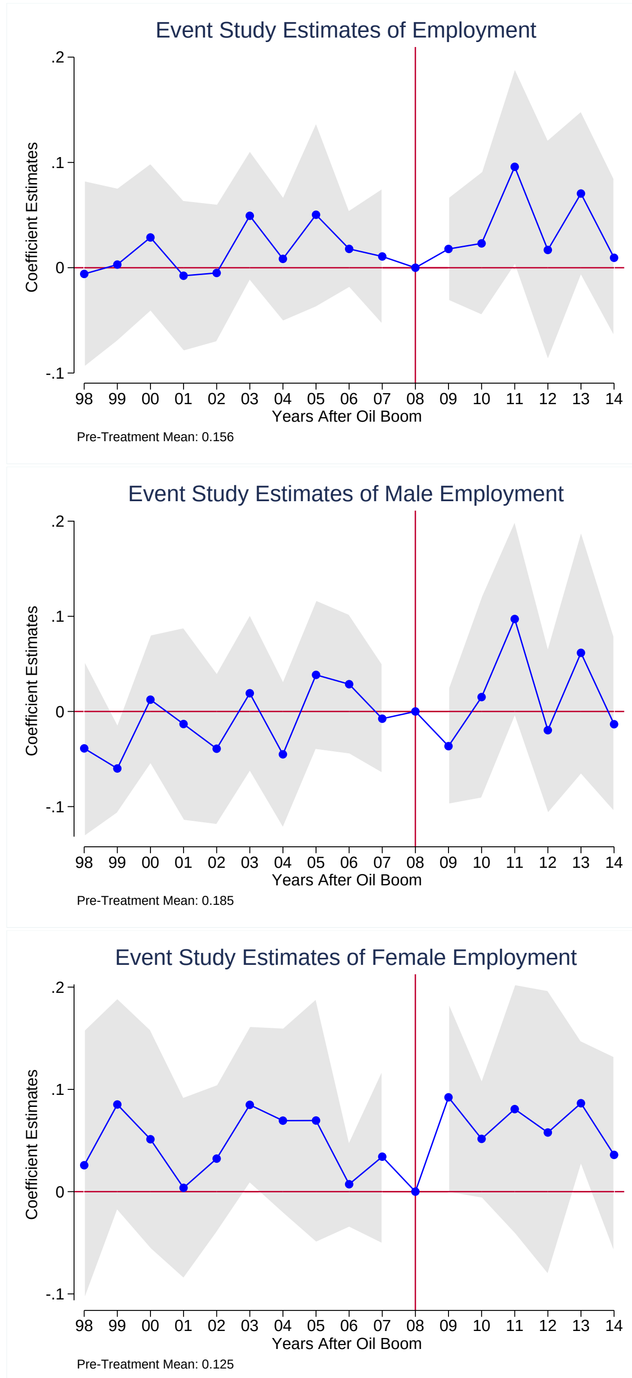


Figure 2.20: Event Study Estimates of 4 Year College

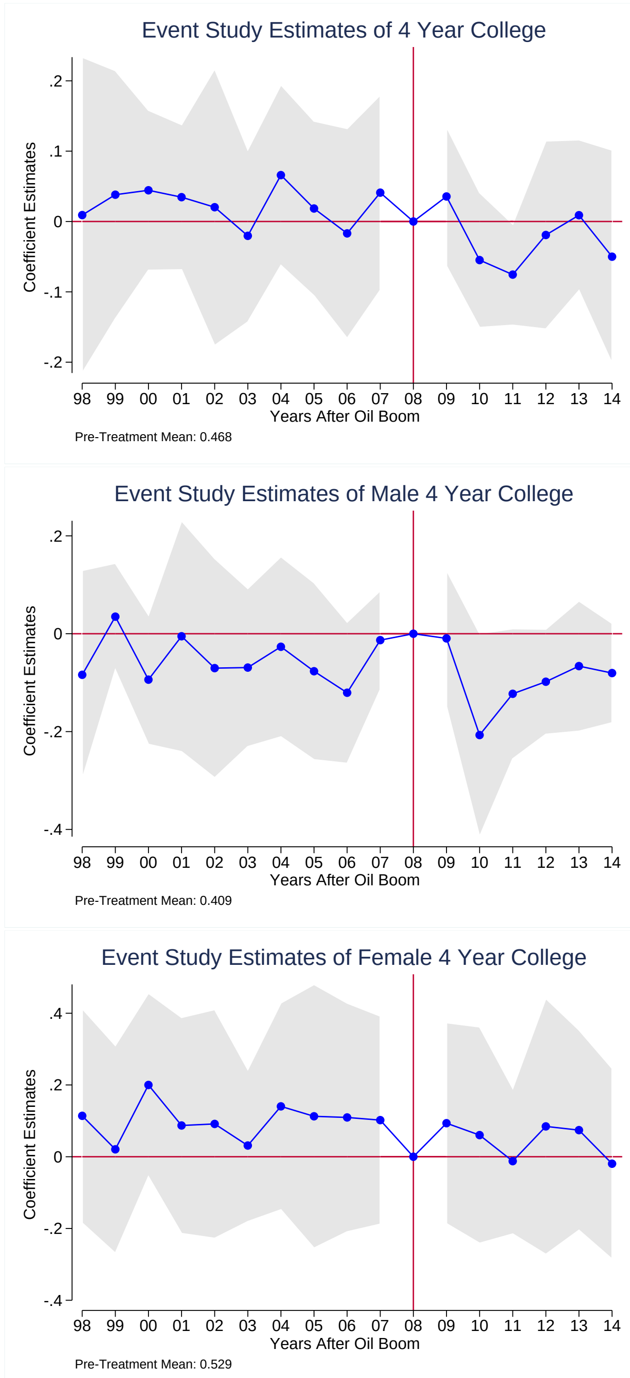


Figure 2.21: Event Study Estimates of 2 Year College

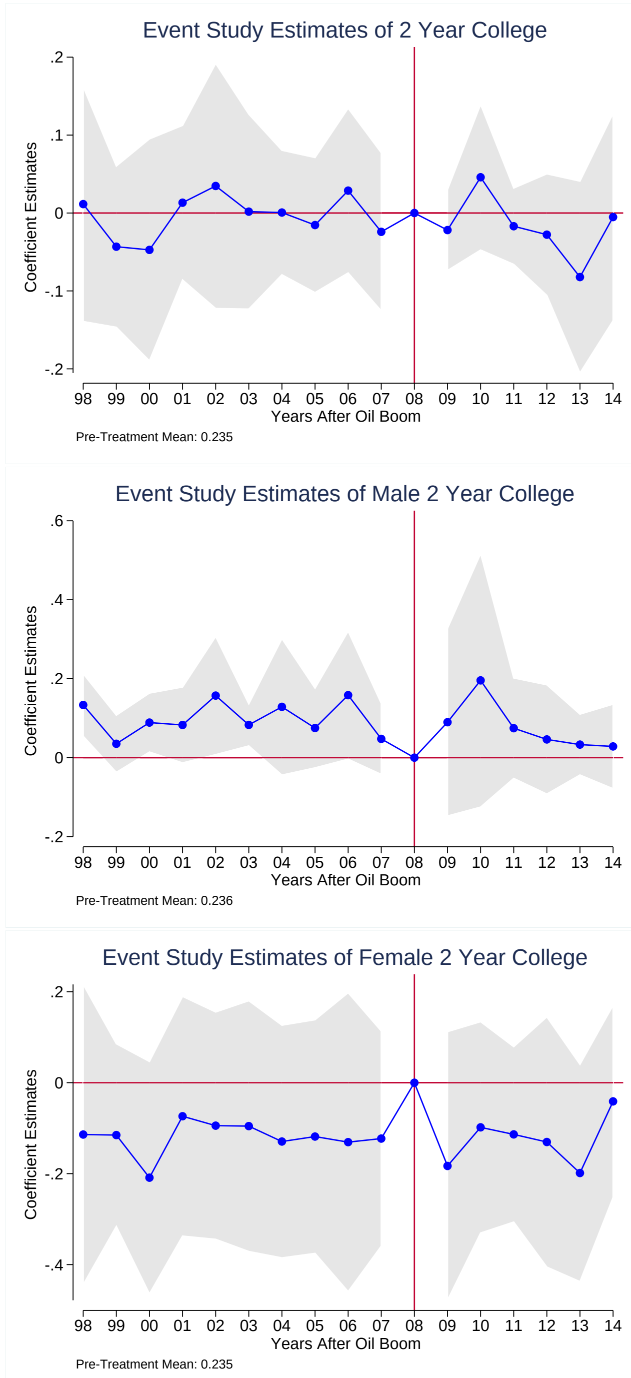


Figure 2.22: Event Study Estimates of Military Enrollment

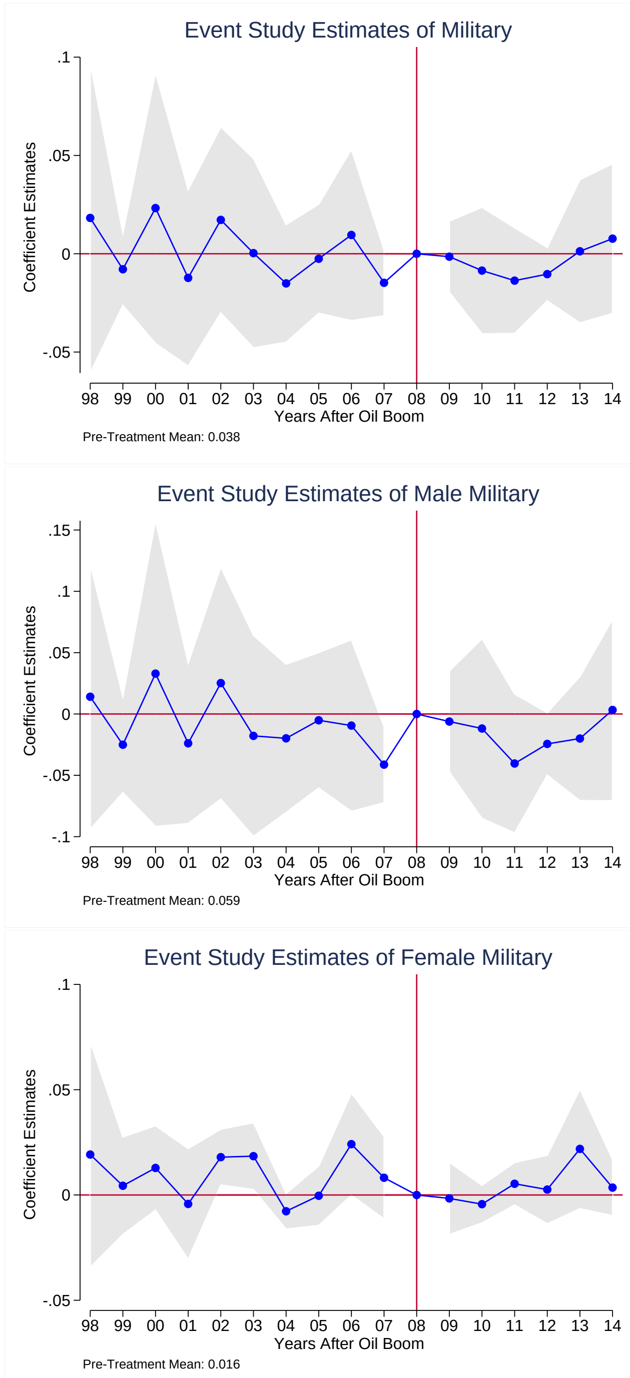


Table 2.1: NDUS Enrollment Summary Statistics

Mean	College	4 Year	2 Year	Regional	Research
Non-Oil & Pre-Boom	0.715	0.461	0.255	0.178	0.283
Non-Oil & Post-Boom	0.790	0.466	0.324	0.177	0.290
Core Oil & Pre-Boom	0.766	0.512	0.254	0.291	0.221
Core Oil & Post-Boom	0.726	0.396	0.330	0.225	0.171

Notes: Reported numbers are NDUS enrollment rates by county of residence, defined by equation 2.2. College rate includes enrollment in all 11 NDUS colleges. The 4 year enrollment rate is composed of the regional and research enrollment rates. Core Oil counties are defined by the state of North Dakota (Center, 2017). The 4 core oil counties are Mountrail, Williams, McKenzie, and Dunn.

Table 2.2: Estimated Effects on NDUS Student Enrollment Rates

VARIABLES	(1) College	(2) 4 Year	(3) 2 Year	(4) Regional	(5) Research
Core-Oil&Post	-0.115*	-0.121***	0.00614	-0.0642***	-0.0565***
	(0.0575)	(0.0344)	(0.0286)	(0.0229)	(0.0178)
Constant	0.664***	0.578***	0.0859***	0.376***	0.202***
	(0.0191)	(0.0136)	(0.0109)	(0.00624)	(0.0109)
Observations	612	612	612	612	612
R-squared	0.750	0.839	0.829	0.812	0.933
Year FE	YES	YES	YES	YES	YES
County FE	YES	YES	YES	YES	YES
DepVar Mean	0.766	0.512	0.254	0.291	0.221

Notes: Each column represents a separate regression by type of college. All models include year and county fixed effects. Standard errors are clustered at the county level. *** p<0.01, ** p<0.05, * p<0.1

Table 2.3: Estimated Effects on NDUS Student Enrollment Numbers

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Ln(College)	Ln(4 Year)	Ln(2 Year)	Ln(Regional)	Ln(Research)
Core-Oil&Post	-0.0961	-0.178**	0.0898	-0.220**	-0.190**
	(0.0709)	(0.0828)	(0.108)	(0.108)	(0.0781)
Constant	4.447***	4.276***	2.685***	3.638***	3.355***
	(0.0276)	(0.0298)	(0.0465)	(0.0447)	(0.0341)
Observations	742	742	742	742	738
R-squared	0.980	0.975	0.956	0.934	0.974
Year FE	YES	YES	YES	YES	YES
County FE	YES	YES	YES	YES	YES
DepVar Mean	5.628	5.200	4.384	4.525	4.429

Notes: Each column represents results from a separate regression by type of college. The dependent variable is the natural log of the number of students enrolled in an NDUS college in county *c* in year *t*. Reported estimates are DD estimates from models with year and county fixed effects. Standard errors, clustered at the county level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

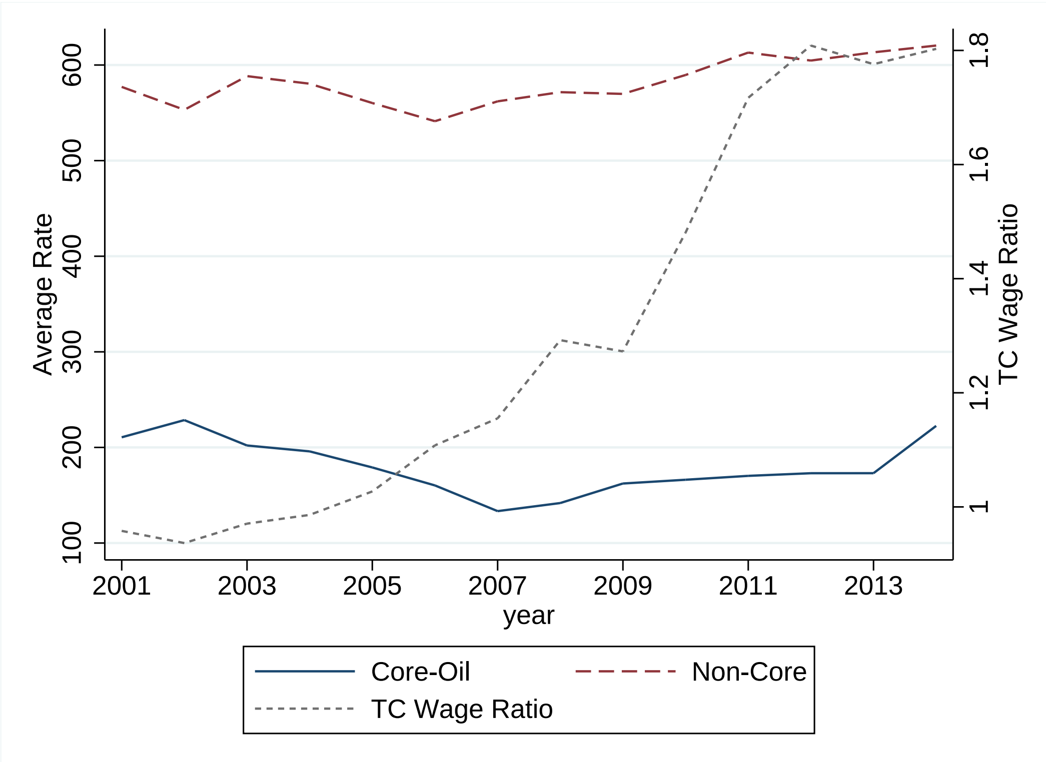
Table 2.4: Post-Graduation Outcomes Summary Statistics

Mean	Employment	2Yr	4Yr	Voc-Tech	Military	Unknown
Total						
Non-Oil & Pre-Boom	0.142	0.208	0.463	0.091	0.033	.064
Non-Oil & Post-Boom	0.141	0.268	0.423	0.070	0.027	.071
Core-Oil & Pre-Boom	0.159	0.270	0.424	0.055	0.033	.059
Core-Oil & Post-Boom	0.234	0.298	0.327	0.047	0.022	.072
Males						
Non-Oil & Pre-Boom	0.174	0.212	0.381	0.112	0.053	.068
Non-Oil & Post-Boom	0.181	0.275	0.341	0.084	0.045	.074
Core-Oil & Pre-Boom	0.189	0.291	0.352	0.063	0.049	.055
Core-Oil & Post-Boom	0.277	0.273	0.285	0.052	0.036	.077
Females						
Non-Oil & Pre-Boom	0.108	0.200	0.551	0.069	0.013	.061
Non-Oil & Post-Boom	0.098	0.256	0.513	0.057	0.009	.065
Core-Oil & Pre-Boom	0.122	0.252	0.498	0.046	0.014	.068
Core-Oil & Post-Boom	0.190	0.311	0.380	0.042	0.006	.069

Notes: Reported numbers are the fraction of males and females with the respective post-graduation outcome. Core Oil counties are defined by the state of North Dakota (Center, 2017). The 4 core oil counties are Mountrail, Williams, McKenzie, and Dunn.

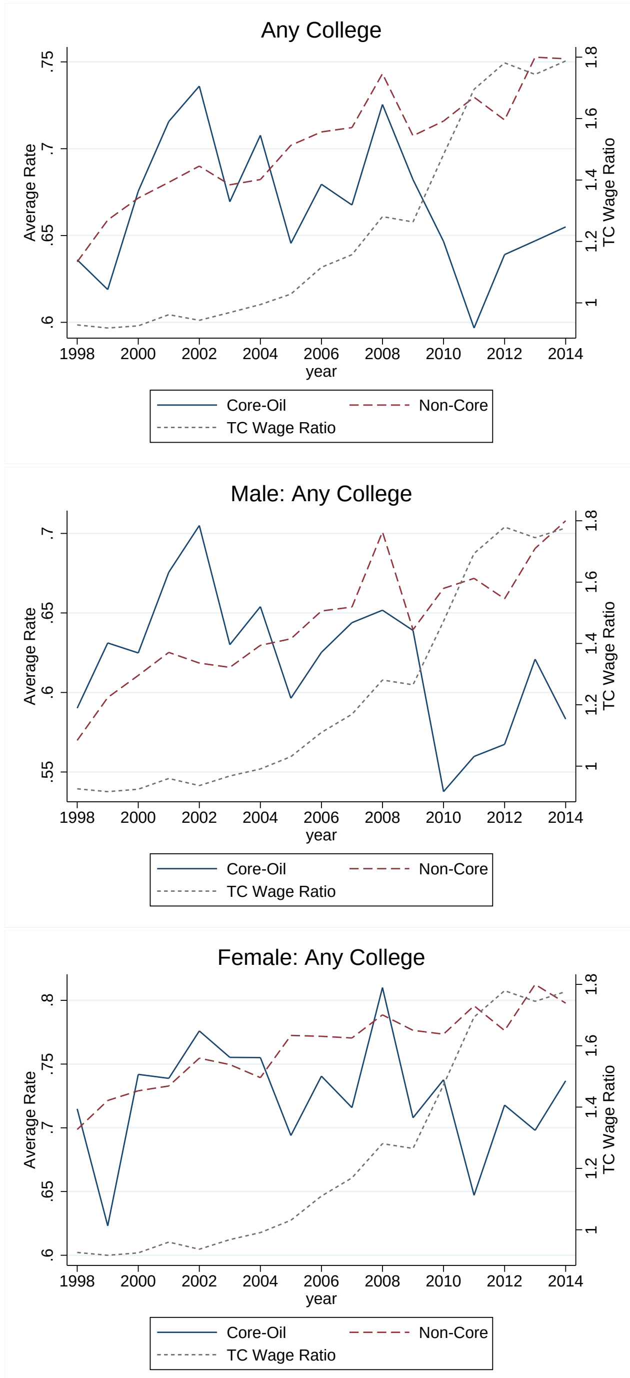
2.8 Appendix

Figure 2.A1: Number of High School Graduates



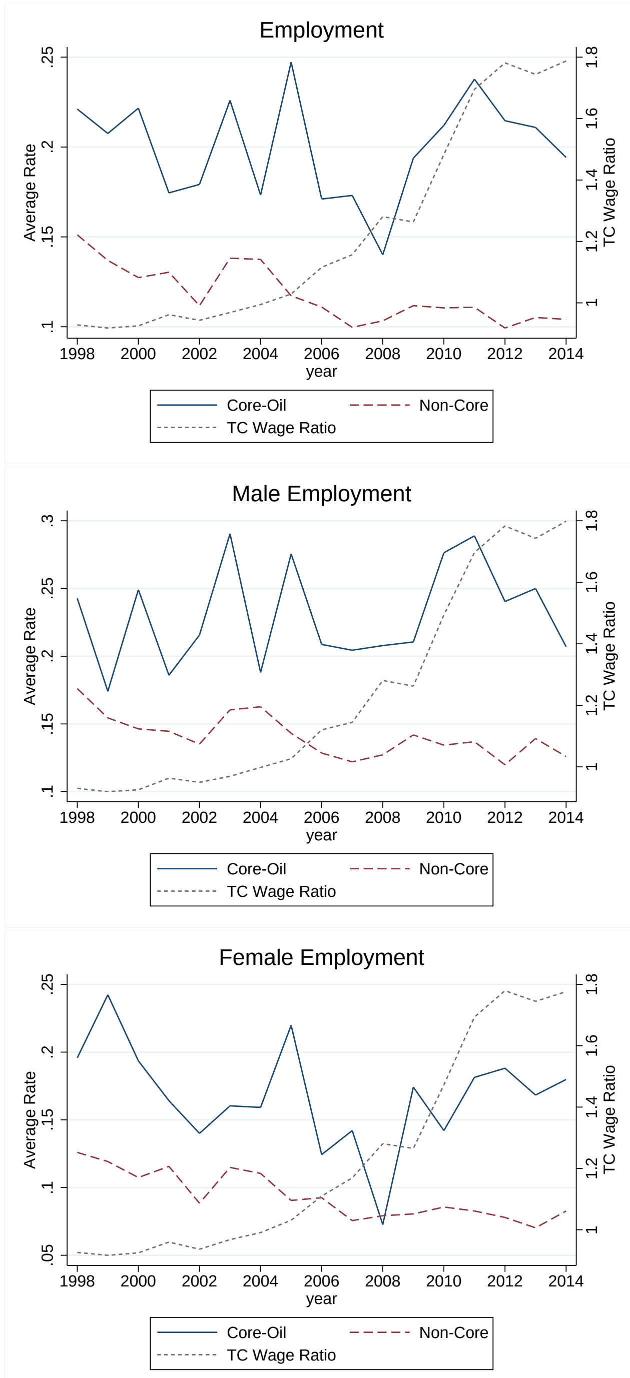
Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties.

Figure 2.A2: College Enrollment Rate Trends



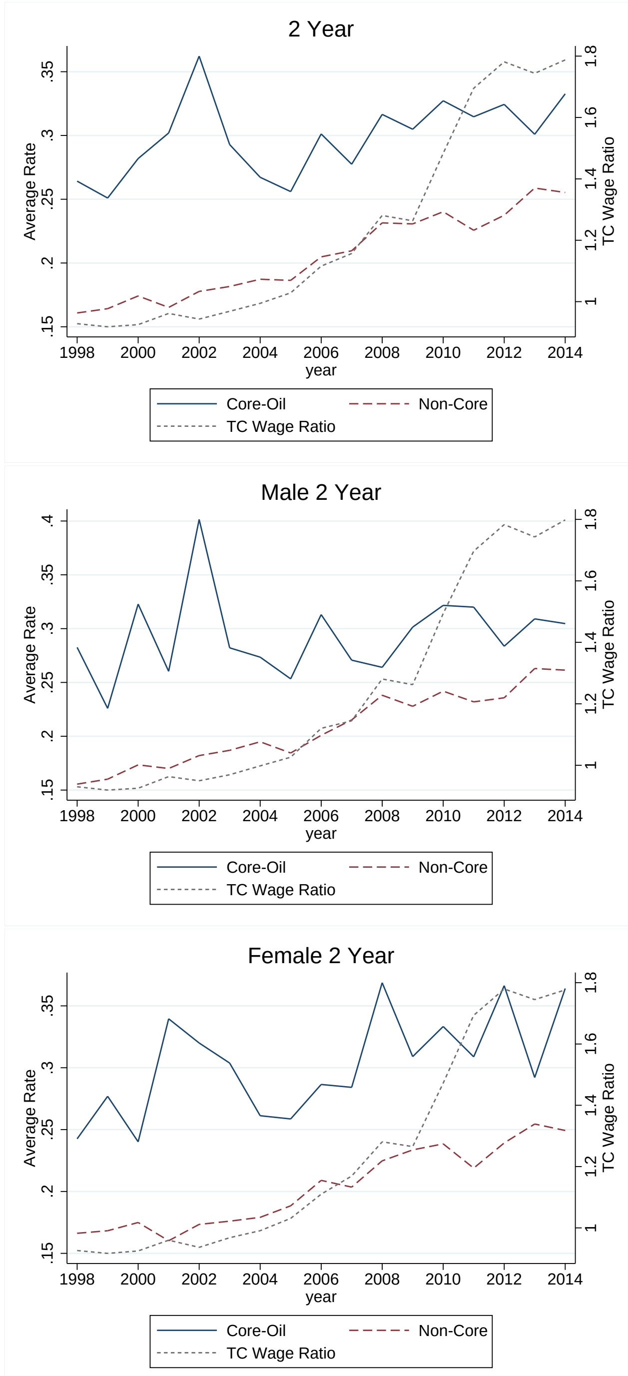
Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties. "Any College" is defined as enrolled in a 2 year or 4 year college.

Figure 2.A3: Employment Rate Trends



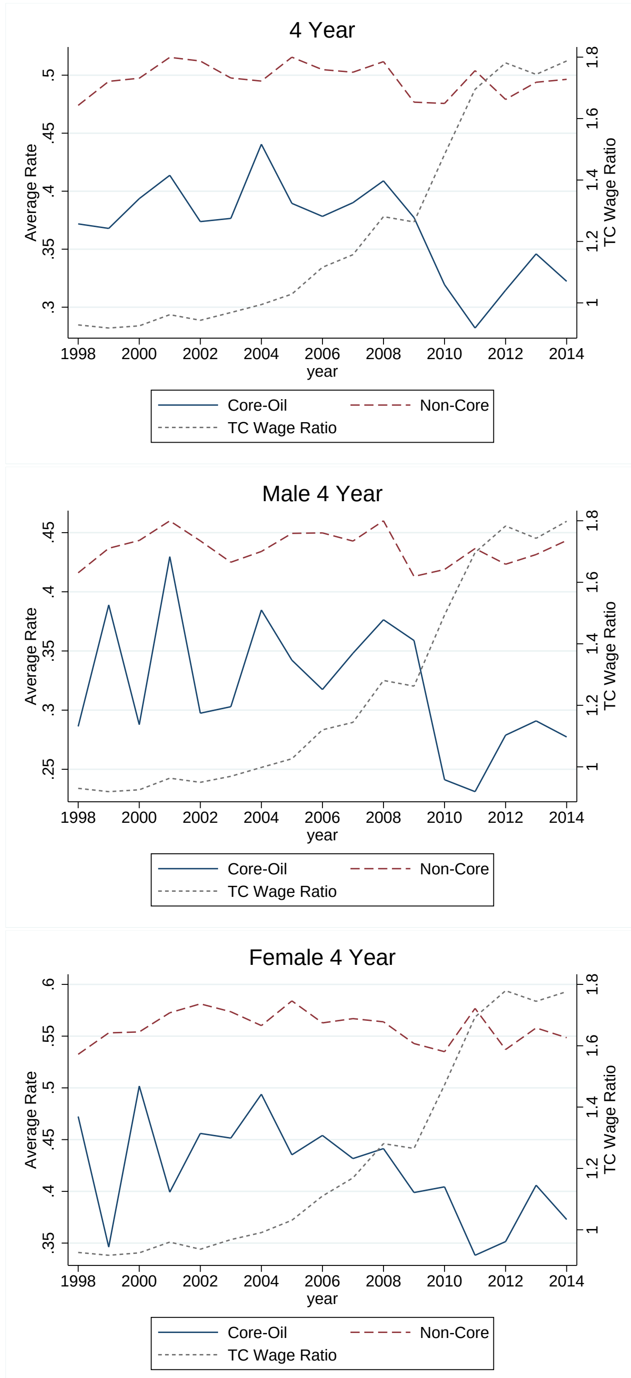
Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties.

Figure 2.A4: 2 Year College Enrollment Trends



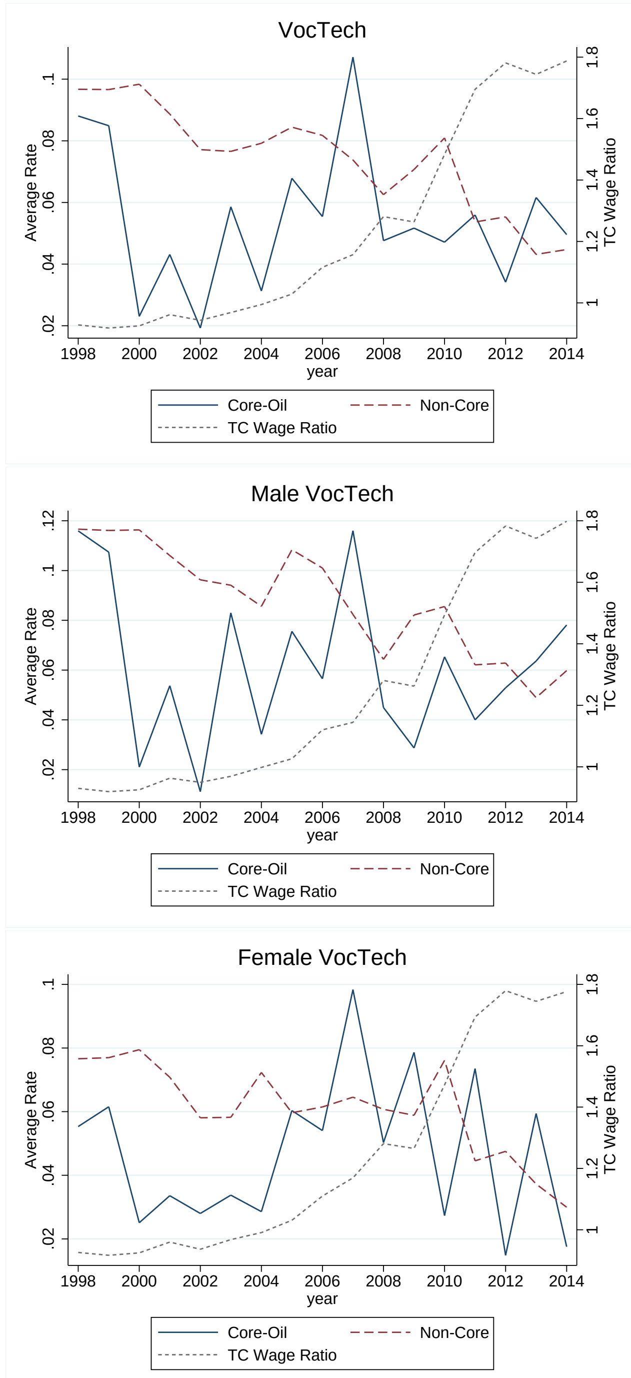
Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties.

Figure 2.A5: 4 Year College Enrollment Trends



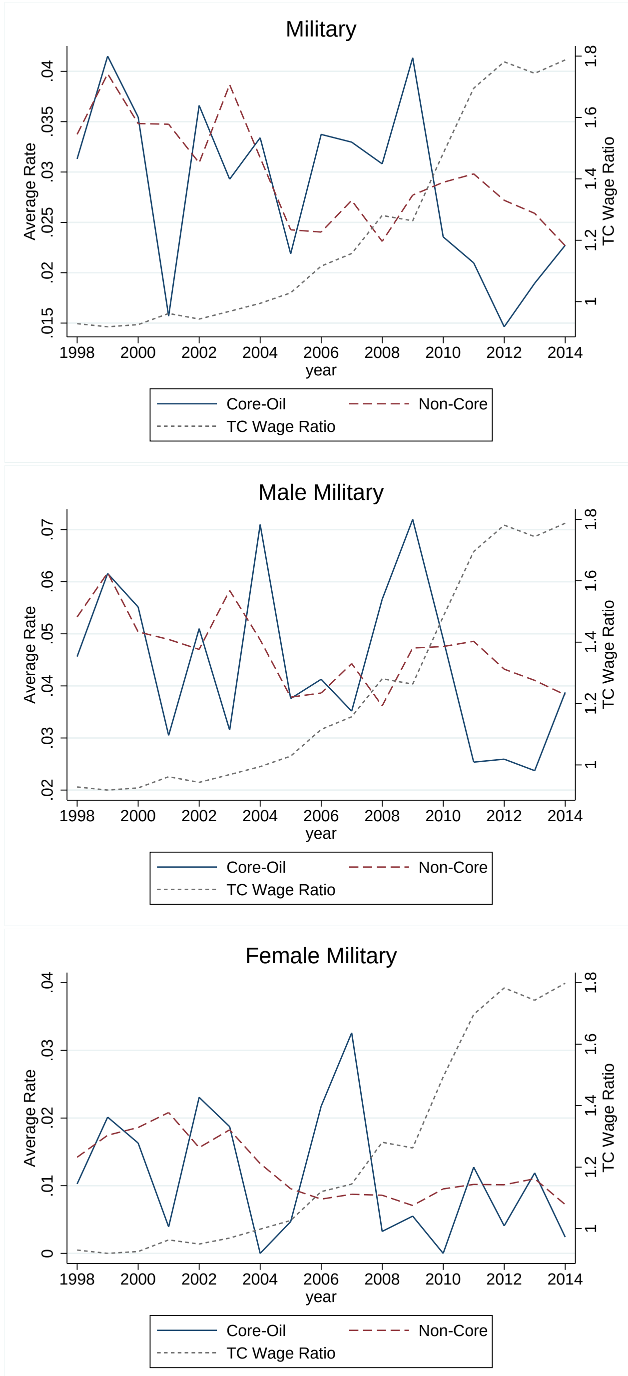
Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties.

Figure 2.A6: Voc-Tech Enrollment Trends



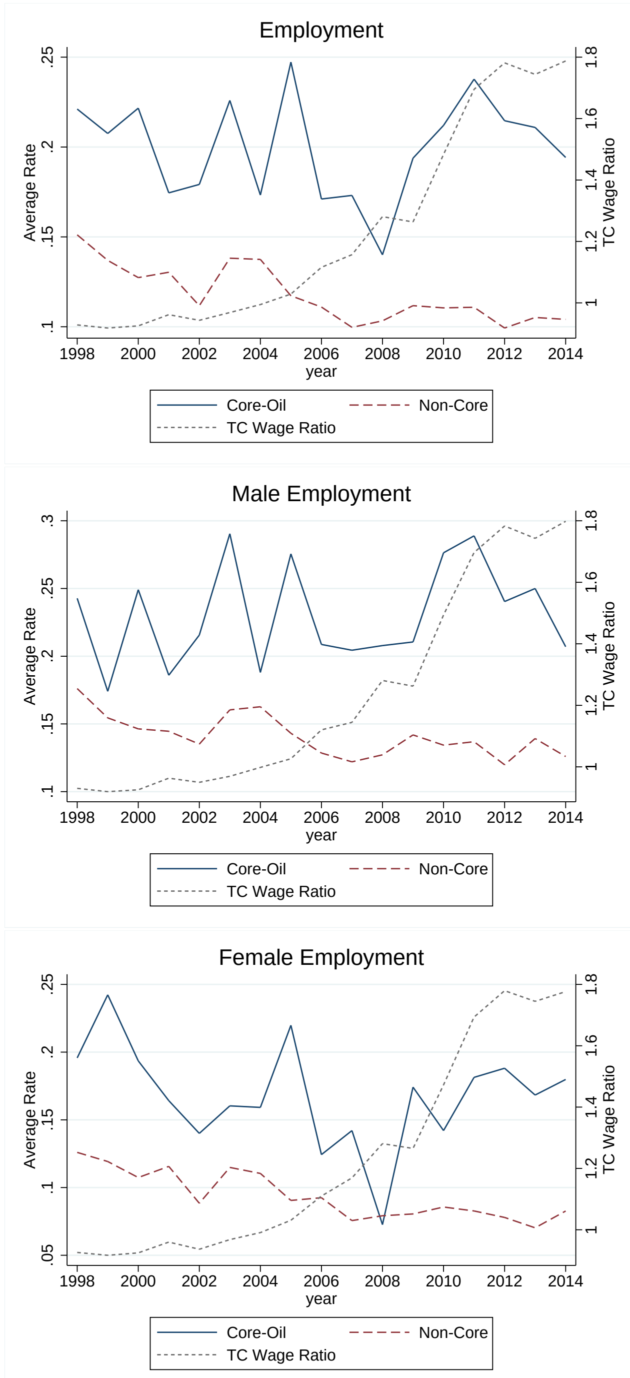
Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties.

Figure 2.A7: Military Enrollment Trends



Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties.

Figure 2.A8: Unknown Decision Trends



Notes: TC Wage Ratio is the ratio of mean weekly wages in core-oil counties relative to non-oil counties.

CHAPTER 3

ECONOMIC CONDITIONS AND SLEEP

3.1 Introduction

The Centers for Disease Control and Prevention (CDC) recommends that adults ages 18 to 60 obtain at least 7-8 hours of sleep per night (CDC, 2017). Short term sleep deficiency lowers cognitive performance and can increase the probability of motor vehicle and work related accidents. Smith (2016) shows that even slight changes in sleep duration can have significant societal costs. The author exploits daylight saving time, finding that the program increased fatal car crash risk by over 5%, causing over 30 deaths per year between 2002-2011. Other literature studies the link between sleep and productivity. Gibson and Shrader (2018) use exogenous variation in sunset time, finding that a one-hour increase in location specific weekly sleep increases wages by 1.1% in the short run and 5% in the long run. The medical field has studied sleep and longer term health outcomes. A CDC report from 2014 emphasized that sleeping less than 7 hours per night is linked to increased risk for diabetes, high blood pressure, coronary heart disease, obesity, and all-cause mortality (Liu et al., 2016). The report highlighted that more than one third of adult respondents report less than 7 hours of sleep per night. Literature from multiple disciplines suggests that sleep deficiency is a prevalent issue with significant societal costs.

Recent papers have exploited the American Time Use Survey (ATUS) to analyze economic conditions and time use. Colman and Dave (2013) find that sleep duration is countercyclical. In further support of this claim, Aguiar et al. (2013) estimate that about 30% of foregone market work hours during the Great Recession were devoted to additional time spent sleeping and watching television. However, no research has considered that economic conditions may differentially impact weekday and weekend sleep behavior. Figure 3.1 motivates this separate analysis, showing that individuals average 340 minutes of work on weekdays but only 89 minutes on weekends.

Meanwhile, Figure 3.2 shows employed individuals sleep 75 minutes more on weekend days than weekdays. Prior literature documenting countercyclical sleep may be driven by sleep behavior on weekdays, where work minutes are concentrated.

3.2 Data and Methodology

I use the 2003-2015 multi-year ATUS, a survey administered by the Bureau of Labor Statistics (BLS). Approximately 12,000 individuals are surveyed every year, spread evenly across months, in which respondents are a subset of households who have finished their final month of the Current Population Survey. The time-use diary summarizes a respondent's activities from 4 a.m. the previous day to 4 a.m. on the interview day. Surveys are conducted every day of the week, while more surveys are conducted Saturday and Sunday to improve precision.

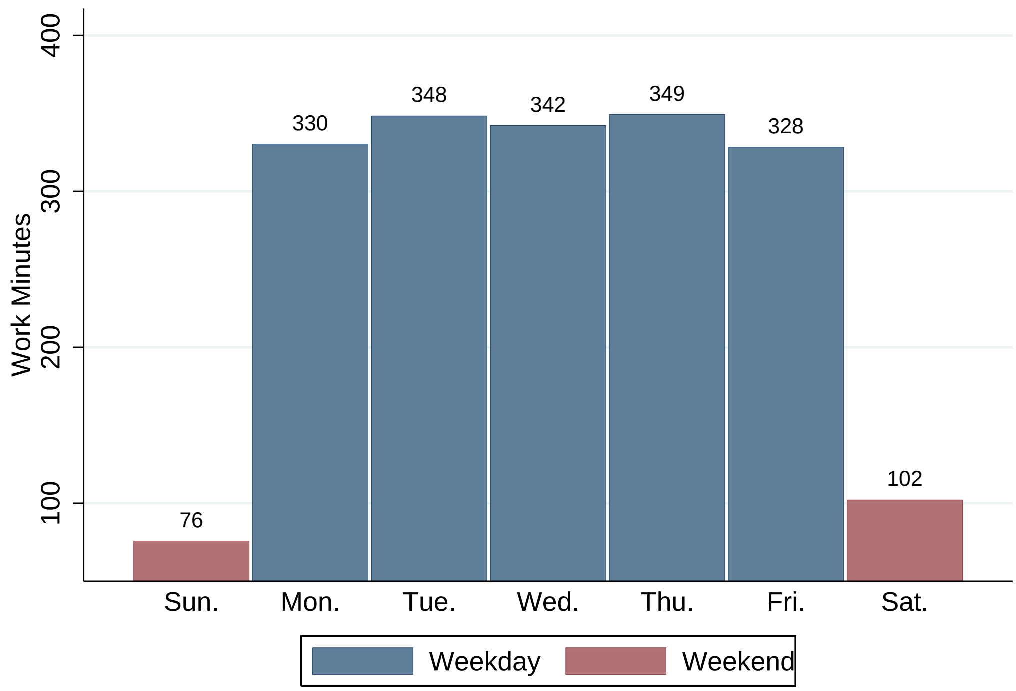
Table 3.1: Average Sleep by Great Recession Severity

	2003-2007	2008-2010	2011-2015
Weekday Sleep			
Above Median	479.976	483.082	495.552
Δ employment	(122.96)	(124.05)	(125.30)
Below Median	480.104	479.704	489.138
Δ Employment	(124.19)	(122.36)	(120.56)
Weekend Sleep			
Above Median	550.857	551.658	556.845
Δ Employment	(137.48)	(140.64)	(136.84)
Below Median	545.163	552.141	556.390
Δ Employment	(137.62)	(135.35)	(137.69)

Notes: Between 2007 and 2010, mean Δ *employment* was -3 percentage points in the below median sample and -5.6 percentage points in the above median sample.

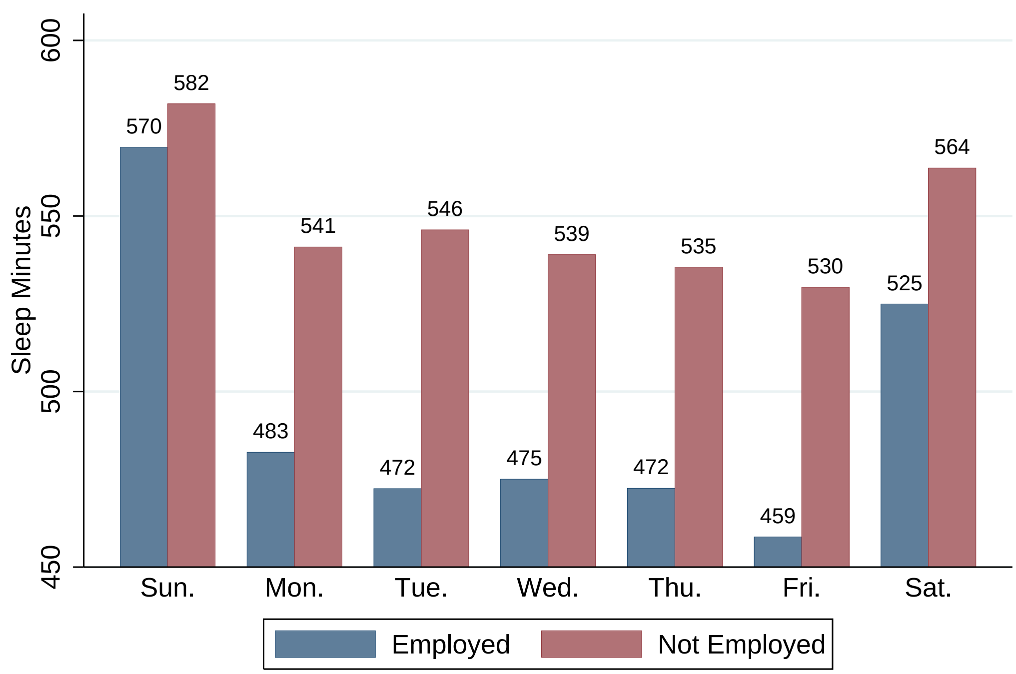
Given that surveys are conducted at a monthly level and state indicators of respondents are observed, I exploit economic variation at the month-state level. Following Colman and Dave (2013), I restrict analysis to observations with at least 23 documented hours (93.9% of

Figure 3.1: Average Minutes Worked per Day



Sample means are for individuals ages 25 to 55 with at least 23 hours of reported time use.

Figure 3.2: Sleep Structure by Employment Status



Sample means are for individuals ages 25 to 55 with at least 23 hours of reported time use.
Not Employed: unemployed and individuals not in the labor force.

observations) and to respondents ages 25 to 55. The descriptive statistics in Table 3.1 suggest that weekday sleep increased more in states that experienced greater employment loss during the Great Recession while weekend sleep increased more in states that were less impacted.

To empirically study the impact of economic conditions on sleep, I estimate model (3.1) via OLS, where Y_{isdmt} denotes minutes of sleep reported by individual i in state s on day of week d in month m in year t. X_{ismt} is a vector of individual characteristics that may affect sleep duration, including age, gender, race, marital status, number of children, indicator for having a child under 3, education, gender and race interacted with education, industry occupation code, indicator for whether the interview day was a holiday, and an indicator for incomplete time diary. E_{smt} is the civilian employment-population ratio of state s in month m in year t. State fixed effects absorb time invariant unobserved heterogeneity of state specific factors. Month, day of week, and year fixed effects are also included while standard errors are clustered at the state level. This empirical design parallels the large literature of economic conditions and health outcomes (Ruhm, 2000, 2005; Charles and DeCicca, 2008).

$$Y_{isdmt} = \beta X_{ismt} + \gamma E_{smt} + \alpha_s + \theta_m + \lambda_d + \eta_t + \varepsilon_{isdmt} \tag{3.1}$$

3.3 Results

Table 3.2 displays estimates of specification (3.1). A point estimate of -1.1 (similar to -.97 in Colman and Dave (2013)) in the first row of column 1 confirms previous literature in finding that overall sleep is countercyclical. However, we may expect differential effects for weekdays versus weekends due to sharp contrasts in work and sleep minutes illustrated in Figures 3.1-3.2. Rows 2-3 of column 1 report results of specification (1) estimated separately by weekday versus weekend sleep. Estimates suggest that a one percentage point increase in the employment rate decreases weekday sleep by 2.3 minutes per night but actually increases weekend sleep by 1.8 minutes per night. The Great Recession was particularly salient for minorities and individuals with less education (Engemann and Wall, 2009; Austin, 2009), motivating analysis by these demographics. Columns 2-3 report estimates of specification (3.1) separately for those with and without a Bachelor's degree, with coefficients indicating that effects are driven by individuals with less education. Columns 4-5 suggest that sleep of Blacks, Hispanics, and American Indians (BHAI) is particularly sensitive to the employment rate. Estimates in columns 6-7 suggest that these patterns hold for both genders, though precision is lost.

Table 3.2: Effect of Employment Rate on Sleep

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All	$<$ Bachelor's	$\geq$Bachelor's	White	BHAI	Female	Male	WM$<$ Bachelor's
All	-1.105*	-1.377**	-0.722	-1.153*	-0.997	-1.593**	-0.699	-2.293*
	(0.636)	(0.679)	(1.091)	(0.666)	(1.146)	(0.767)	(1.064)	(1.330)
Observations	92,684	57,533	35,151	62,788	25,779	51,238	41,446	16,850
R-squared	0.111	0.104	0.122	0.111	0.103	0.111	0.113	0.104
Weekday	-2.319**	-3.051***	-1.160	-1.860*	-3.605**	-2.771***	-2.033	-3.880**
	(0.918)	(0.995)	(1.364)	(0.952)	(1.521)	(1.029)	(1.309)	(1.827)
Observations	46,075	28,481	17,594	31,461	12,549	25,372	20,703	8,515
R-squared	0.073	0.076	0.056	0.064	0.083	0.077	0.072	0.071
Weekend	1.786**	2.382**	0.250	0.433	4.946***	1.217	2.396**	1.394
	(0.820)	(1.151)	(0.958)	(1.039)	(1.362)	(1.386)	(1.165)	(1.493)
Observations	46,609	29,052	17,557	31,327	13,230	25,866	20,743	8,335
R-squared	0.059	0.058	0.061	0.056	0.062	0.060	0.063	0.056

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

Notes: The dependent variable is reported daily sleep for respondents ages 25-55. Each cell reports estimates from a separate regression. Controls are described in text. Standard errors are clustered at the state level. Column 4 restricts the sample to non-hispanic white, 5 to black, hispanic, or American Indian, and 8 to white males with less than a Bachelor's degree.

I explore heterogeneity by marital status in Table 3.3, as Engemann and Wall (2009) show the Great Recession decreased single individual employment more than married individual employment. Indeed, columns 1-2 show that results are driven by single individuals while effects for married individuals are muted and statistically insignificant. Columns 3-4 show particularly strong effects of employment on single parent weekday sleep. This is consistent with single parents being less educated, more likely to be of minority, and a demographic strongly impacted by the Great Recession (Mattingly et al., 2011). There is no evidence that higher employment rates increase single parent weekend sleep, suggesting single parents lose more sleep than other demographics during economic expansions. Columns 5-6 exhibit no evidence that the sleep or work of low education married females is sensitive to economic conditions, consistent with earlier results being driven by single individuals.

Table 3.3: Employment and Sleep by Marital Status

	(1)	(2)	(3)	(4)	(5)	(6)
	Single	Married	Single Parent	Married Parent	MF-Sleep	MF-Work
All	-1.714	-0.837	-5.680***	0.381	-0.770	-0.541
	(1.104)	(0.677)	(1.499)	(0.690)	(1.364)	(1.939)
Observations	37,689	54,995	14,758	42,938	16,893	16,893
R-squared	0.101	0.118	0.112	0.123	0.112	0.334
Weekday	-4.079**	-1.363	-8.127***	0.0141	-1.491	-1.301
	(1.581)	(0.942)	(2.025)	(0.864)	(1.902)	(2.704)
Observations	18,702	27,373	7,242	21,298	8,303	8,303
R-squared	0.083	0.065	0.100	0.066	0.071	0.341
Weekend	3.709**	0.534	-0.0281	1.105	1.253	2.292
	(1.597)	(0.978)	(2.680)	(1.087)	(1.994)	(2.312)
Observations	18,987	27,622	7,516	21,640	8,590	8,590
R-squared	0.051	0.066	0.066	0.075	0.073	0.100

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

Notes: The dependent variable is reported daily sleep for respondents ages 25-55 except for column 5. Each cell reports estimates from a separate regression. Control variables are the same as in 3.2. Standard errors are clustered at the state level. Column 5 restricts to married females without a Bachelor's degree while column 6 does the same but explores work minutes as the dependent variable.

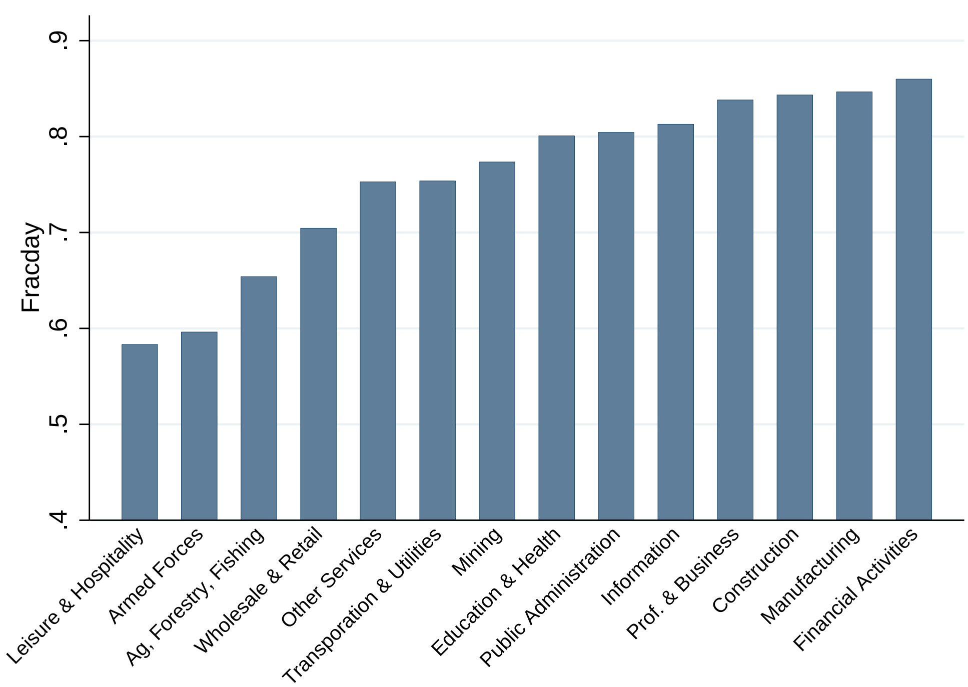
We may expect heterogeneity across occupation industries due to varying work week schedules.

For every CPS major industry code, I create the variable

$$\text{Fracday} = \frac{x_{wd}}{x_{wd} + x_{we}},$$

where x_{wd} (x_{we}) is mean reported work minutes on a weekday (weekend) day. Figure 3.3 shows that Fracday ranges from .58 in leisure and hospitality to .86 in the financial activities sector. An increase in the employment rate should particularly impact the weekday sleep of individuals who work in weekday heavy industries. Columns 3-4 of Table 3.4 estimate specification (3.1) separately for individuals who work in industries

Figure 3.3: Workweek Structure by Industry



Notes: Fracday $= \frac{x_{wd}}{x_{wd}+x_{we}}$, where x_{wd} (x_{we}) is mean reported work minutes on a weekday (weekend) day.

Table 3.4: Employment Effects by Workweek Structure

	(1) Employed	(2) Not Employed	(3) >Med Fracday	(4) ≤Med Fracday	(5) Blue-Collar	(6) White-Collar
All	-1.346*	0.222	-1.384	-0.587	-3.308*	0.886
	(0.791)	(1.600)	(0.957)	(1.061)	(1.732)	(0.877)
Observations	74,324	18,360	36,640	42,599	14,744	15,392
R-squared	0.116	0.068	0.137	0.094	0.152	0.145
Weekday	-2.275**	-1.493	-2.923**	-0.699	-6.001***	0.0778
	(1.050)	(2.142)	(1.116)	(1.427)	(1.830)	(1.185)
Observations	37,088	8,987	18,320	21,094	7,310	7,791
R-squared	0.048	0.070	0.052	0.053	0.061	0.071
Weekend	1.089	3.859	2.857**	-0.176	3.473	3.278**
	(0.883)	(2.316)	(1.295)	(1.408)	(2.271)	(1.476)
Observations	37,236	9,373	18,320	21,505	7,434	7,601
R-squared	0.061	0.060	0.079	0.052	0.099	0.084

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

Notes: The dependent variable is reported daily sleep for respondents ages 25-55. Each cell reports estimates from a separate regression. Column 1 restricts the sample to employed while column 2 restricts to the unemployed and out-of-labor force. Fracday $= \frac{x_{wd}}{x_{wd}+x_{we}}$, where x_{wd} (x_{we}) is mean reported work minutes on a weekday (weekend) day. Column 3 restricts to below median Fracday while 4 is above median. Columns 5-6 split the ≥Med Fracday sample by work type. Blue-Collar: construction and manufacturing. White-Collar: financial activities and professional and business services. Control variables are the same as in 3.2. Standard errors are clustered at the state level.

with above and below median Fracday values. Weekday and weekend sleep results are driven by industries with weekday concentrated work schedules. Columns 5-6 split the top four "Fracday" industries into blue-collar and white-collar segments. Estimates indicate that the strong negative effect of employment on weekday sleep is driven by blue-collar, weekday centric industries.

3.4 Conclusion

This is the first paper to uncover that economic expansions decrease weekday sleep but actually increase weekend sleep. A limitation of this analysis is that the welfare consequences of these changes in sleep are not obvious. The CDC recommends a consistent sleep schedule and the

National Institutes of Health (NIH) emphasizes that sleeping more on the weekend doesn't fully correct one's sleep debt (Patlak, 2005). If this is true, then the value of sleep depends on both the average and variance of sleep within a week. If economic expansions reduce average sleep and increase the gap between weekend and weekday sleep, then prior work relying on weekly sleep averages underestimate the cost of lost sleep. As sleep deprivation is a key cause of motor vehicle crashes, my findings have implications for papers researching economic conditions and motor vehicle fatalities, accident related death, workplace injury, or other sleep related outcomes. Differential results concerning economic conditions and sleep by day type may be one mechanism for which to expect economic conditions to impact other sleep related outcomes diversely depending on day of the week.

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