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DISCUSSION PAPER SERIES

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ABSTRACT

Soccer's Record on the Road: The Effect of Late-Night Sporting Events on Fatal Car Crashes

Sleep deprivation imposes significant public health and economic burdens. While researchers studying events like daylight saving time have quantified the impacts of population-wide sleep shifts, less is known about the consequences of acute, voluntary, and recreation-driven sleep loss. This paper investigates this gap by studying the 2002 FIFA World Cup, hosted in South Korea and Japan. The extreme time difference meant that US-based fans sacrificed significant sleep to watch live matches. We track fatal accidents in areas with large German populations on days when the German national soccer team played early morning games. Germany has by far the largest number of Americans who trace their ancestry to a foreign country, and they made it to the final of this World Cup. Areas with greater than 30% German heritage experienced increases in fatal car accidents of 35% relative to control areas after German games. The effects are dose-dependent and rise as the share of the German population increases. Our results are larger for crucial tournament games and non-alcohol-related incidents, consistent with sleep-deprived driving. Effects are driven by male drivers, mirroring World Cup viewer demographics. Placebo tests using the 2006 World Cup, where no games were played during normal U.S. sleeping hours, confirm that sleep disruption, not the sporting event itself, drives our findings.

JEL Classification: I12, R41, D62
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1. Introduction

Sleep deprivation is a significant public health and economic burden. Beyond physiological and cognitive impairments, insufficient sleep can impose substantial negative externalities through reduced productivity, increased healthcare utilization, and a higher propensity for accidents. Economists and public health researchers have sought to quantify these impacts, leveraging natural experiments such as daylight saving time (DST), school start time changes, and time zone boundaries to isolate the causal effects of sleep disruption (e.g., Ghosh and Sood, 2007, Smith, 2016, Gibson and Shrader, 2018, Costa-Font, Fleche, et al., 2024). Although valuable and policy-relevant, the variation that generates these estimates is distinct from typical acute sleep loss: Adults often miss many hours of sleep, may lose sleep for multiple days in a short period, and may lose sleep because they are substituting recreational activities for sleep.

In this paper, we study the effects of this type of acute, repeated, and recreation-driven sleep loss on fatal car accident rates. We use the 2002 FIFA Men's World Cup[1], broadcast from South Korea and Japan, as a natural experiment, since games took place either in the middle of the night or in the early morning hours for time zones in the United States. For US-based fans, watching key games live meant sacrificing sleep–often several hours over multiple nights–due to the extreme time difference. We test whether the resulting entertainment-driven exhaustion leads to more fatal car accidents later that day, and, if so, which types of accidents drive our results.

To study this question, we leverage the unique institutional features of the World Cup. Each night of the tournament featured different national teams playing, and fans of those national teams are geographically distributed based on ancestry. We collect detailed demographic data from the 2000 US Census to identify Public Use Microdata Areas (PUMAs) with high concentrations of residents likely to be ardent fans of teams playing late-night games. We focus on areas with significant German heritage for two reasons. First, over 30 million US residents claimed German heritage in 2000, 50% more than claimed ancestry from any other nation in the 2002 World Cup. Second, Germany had a very successful tournament, making it to the final game before losing to Brazil. No team in the tournament played more games than Germany's seven, and viewership numbers increased as the tournament progressed.

We link PUMA-level fan profiles to daily fatal car accident counts sourced from the Fatal Accident Reporting System (FARS). We then estimate difference-in-difference-style models comparing how fatal car accident rates change in "high-German" PUMAs when their team plays a late game to any concurrent changes happening in "low-German" PUMAs and to the "high-German" PUMAs themselves on days without games.

We find that World Cup sleep loss has a significant impact. For high-percentage German PUMAs, German World Cup games increase the number of fatal car accidents that day. For

[1]We will refer to the Men's World Cup simply as the World Cup in the rest of the paper, though it is important to distinguish it from the Women's World Cup, which has a similar format but takes place in different years and different countries.

PUMAs with greater than 30% German heritage, fatal car accidents increase by .024 accidents per PUMA per day, an increase of 35% compared to the mean. These increases are larger for more highly concentrated German PUMAs. For PUMAs with at least 40% German heritage, our point estimate increases to .037 crashes per day (46%), and for PUMAs with at least 50% German heritage, we see an increase of .105 crashes per PUMA per day, a 122% increase from the mean.

Our analysis points to sleep loss from watching soccer games as the mechanism behind these results. Estimates get larger when we focus only on Germany's most important and salient games, their opening match, and their four knockout round ties, including the final. Further, our results are driven almost entirely by accidents which do not involve alcohol, suggesting that they are caused by sleep loss as opposed to increased alcohol consumption. Finally, the increases that we observe are almost entirely from accidents that involve a male driver, consistent with higher male viewership of the World Cup.

We perform a battery of robustness tests. We first show that our specifications are robust to our choice of control days, as well as several transformations of our outcome variable to address accident over-dispersion and left-censoring. In addition, the increases we see are from accidents occurring during 'clear' weather conditions, which suggests that weather is not a confounding omitted variable. Next, we conduct a placebo analysis using the 2006 World Cup, where Germany also performed well but matches took place during normal waking hours for US-based fans. We find no impact, suggesting that our results are not due to World Cup matches in general, but only matches that interfere with sleep. As an additional placebo check, we assign treatment to random days in July instead of June. For each of our six main specifications, our actual estimates are larger than over 99% of our July placebos, suggesting that the effects we find are unlikely to occur by chance.

Prior literature

We contribute to three strands of the literature. First, we add to the growing body of work that uses natural experiments to quantify the real-world consequences of sleep disruption on outcomes like traffic safety. Many studies leverage Daylight Saving Time (DST) transitions, showing increases in fatal vehicle crashes (e.g, Smith, 2016) and workplace injuries (Barnes and Wagner, 2009) due to acute sleep loss. Additional papers examine time zone boundaries and sunset times to identify chronic sleep deficits and their impacts on health (Giuntella and Mazzonna, 2019), human capital accumulation (Jagnani, 2024), and labor market outcomes (Costa-Font, Fleche, et al., 2024; Kajitani, 2021). These papers study population-wide shifts that often induce relatively modest sleep changes or have mixed, short-term effects (Harrison, 2013, Steponenaite et al., 2025). We study a distinct and relevant type of exogenous sleep shock—late-night sports broadcasts—which are substantial, acute, and recreation-driven.

Second, our research directly engages with the extensive literature demonstrating the detrimental effects of acute sleep deprivation on cognitive function, reaction time, and driving performance. Studies link insufficient sleep to impaired academic performance and labor produc-

tivity,[2] and a heightened risk of motor vehicle accidents.[3] While much of this evidence relies on self-reported sleepiness or controlled laboratory experiments, our paper provides new, quasi-experimental tests of this link in a large population by leveraging predictable, event-driven sleep loss.

Third, we contribute to the literature on the economic allocation of time and the opportunity cost of sleep. Seminal work by Biddle and Hamermesh established that increased labor market time reduces sleep, suggesting that sleep is an input affecting wages and productivity (Biddle and Hamermesh, 1990). Subsequent research expanded these ideas by showing how work and family demands lead individuals to 'borrow' time from sleep, especially when demands are high, and that sleep is often sacrificed under duress (Barnes, Wagner, and Ghumman, 2012). These studies primarily focus on sleep loss driven by work or family obligations (e.g., child sleep interruptions impacting maternal labor supply (Costa-Font and Flèche, 2020); There is less evidence on how voluntary, recreation-driven choices to sacrifice sleep impact economic and social outcomes. Our study extends this understanding by examining a context in which individuals choose to incur significant sleep debt for leisure.

The rest of this paper is organized as follows. Section 2 provides background information on the World Cup and the German national team. Section 3 describes our data from FARS and the US Census and provides summary statistics. Section 4 motivates and describes our empirical strategy. Section 5 presents results, heterogeneous effects, and robustness checks. Section 6 concludes.

2. Background

2.1. The World Cup

The World Cup, organized by the Fédération Internationale de Football Association (FIFA), is the most viewed sporting event in the world and is held every four years. The 2002 World Cup was awarded jointly to Japan and South Korea. Thirty-two teams qualify for the tournament after competing against other teams from their respective continental confederations. The tournament begins with a 'round-robin' group stage, where the 32 qualified teams are split into eight groups of four teams each.[4] Each team plays one game against each of the other three teams in their group, with three points awarded for a victory and one point awarded for a draw. After each team has played the other three teams in their group, the top two teams with the most points in each group move on to the 'knockout rounds' of the tournament, where teams play opponents from other groups, and only the winner moves on. After the group stage, 16 teams remain, so there are up to four additional rounds to be played. The winners of the 'Round of 16' move on to

[2]These papers include Giuntella, Saccardo, et al. (2024), Carrell et al. (2011), Heissel and Norris (2018), Groen and Pabilonia (2019), Costa-Font, Fleche, et al. (2024), Kajitani (2021), and Costa-Font and Flèche (2020)

[3]These papers include Ghosh and Sood (2007), Smith (2016), Garbarino et al. (2016), Vargas-Garrido et al. (2021), Carey and Sarma (2016), Connor et al. (2002), Herman et al. (2014), and Liu et al. (2003)

[4]Starting in 2026, the World Cup will include 48 teams and follow a revised format.

the quarterfinals, then the semifinals, and ultimately the final, where the winner is crowned as the World Cup champion.

The 2002 World Cup was watched by more than 1.5 billion people across the world. Because the 2002 World Cup took place in Japan and South Korea, many of the matches were broadcast in the middle of the night for the US: To watch most matches, viewers had to sacrifice some amount of sleep. The majority of matches began between 2:30 pm and 8:30 pm Korean Standard Time: between 10:30 p.m. to 4:30 a.m. PST, and 12:30 a.m. to 6:30 a.m. Central Time.

Despite the time difference, Nielsen reported a total viewership of over 85 million in the US, with an average gross audience of 1,334,000 per match ("Final World Cup Nielsen Numbers Posted; Ratings Notes" 2002). ESPN, which had the US broadcast rights, reported on the scale of their success: "ESPN's audience is 39% higher – and ESPN2's 52% higher – than the 1998 [World Cup]. U.S. – Germany is ESPN's most-viewed second-quarter show ever (3.77 million homes, 4.36 rating)" (ESPN, 2003). This was a surprising increase relative to the 1998 World Cup, held in France in a more US-friendly time zone.

World Cup viewership translated into lost sleep, and the media highlighted this trade-off. Figure A.1 shows a selection of headlines from contemporaneous newspapers that discuss sleep loss among those who watched the World Cup.

2.2. The German National Team

To estimate the impact of World Cup-related sleep loss on fatal car accidents, we identify areas of the US that were likely to be more affected by the tournament on particular days. We use the shares of various portions of the country with ancestral roots in different nations that participated in the World Cup. Our strategy is similar to a shift-share instrument (Bartik, 1991; Blanchard and Katz, 1992; Goldsmith-Pinkham et al., 2020). Regions with a larger share of residents whose heritage is from a particular country are more likely to watch games involving that nation.

We focus on the German national football team, known colloquially in Germany simply as 'Die Mannschaft', or 'The Team.' Germany has, by far, the most American residents who have ancestral roots in their country out of the 32 nations that participated in the 2002 World Cup. Figure A.2 shows the number of Americans in the 2000 Census who claim heritage from each of the top ten nations that participated in the 2002 World Cup. According to the 2000 Census, there were 30.4 million Americans who claimed German as their main ancestral heritage. The next highest was Ireland with 19.3 million, followed by England with 16.6 million, and Mexico with 15.8 million.

In addition to having the largest pool of American residents, Germany also had a very successful tournament in 2002, making it to the final before losing to Brazil. No team in the 2002 World Cup played more games than Germany. Their opponents in the final, Brazil, do not have enough Americans of Brazilian descent in the 2000 Census to be reported separately. The same is true for the other two teams that made the semifinal, South Korea and Turkey. Aside from Ger-

many, of the 10 countries in Appendix Figure A.2 with the largest populations in the US, four of them (France, Poland, China, and Russia) failed to make it beyond the group stage and therefore only played three matches, another four (Ireland, Mexico, Italy, and Sweden) were eliminated in the Round of 16, meaning they only played four matches, and only England made it to the quarterfinal, where they would also lose to the eventual winners Brazil. To summarize, Germany has a substantially larger population in the US than any other nation, and they participated in every possible game, including the semifinal and final, where ratings are the highest. This gives us the best opportunity to measure the impact of World Cup-related sleep loss on fatal car accidents.

3. Data

3.1. 2000 US Census

We use Integrated Public Use Microdata Series (IPUMS) census data on population characteristics such as the heritage, cultural identity, and geographic location of each person (Ruggles et al., 2025). For this project we utilize the 2000 5% US Census, which we use to calculate the percentage of residents of each Public Use Microdata Area (PUMA) who are of German heritage. PUMAs are the smallest geographic areas identified in the Census and contain at least 100,000 people. The German heritage variable includes primary and secondary ancestry codes 32 and 40, representing Germany and Prussia.

3.2. FARS data

We use data from the US Fatal Accident Reporting System (FARS) that tracks every fatal car accident that occurs in the United States each year, and includes information about the precise date, time, and location of the crash, as well as the local weather conditions when the crash took place. These data also include information about the individuals involved in the crash, including their gender and whether they were suspected of being under the influence of alcohol. The alcohol variable reflects the judgment of law enforcement, taking a value of one if a driver fails a breathalyzer test or if the officer on the scene suspects they were under the influence at the time of the crash. We map each accident to PUMAs using the provided latitudes and longitudes. For each of the 2,071 PUMAs in the United States, we calculate the daily number of fatal accidents for each day in 2002, along with the total number of fatalities.

3.3. Sample construction, selection, and summary statistics

We limit the sample period to the months surrounding the World Cup—May, June, and July—though we demonstrate that our results are not sensitive to wider or narrower bandwidths. Additionally, because four of the seven German World Cup games aired at 7:30 AM Eastern Time (ET), in our baseline analysis we drop all PUMAs on ET, since they received a much smaller sleep

shock.[5]

Appendix Table A.1 displays summary statistics for our sample. We include means for our control group of 906 PUMAs, 132 PUMAs with at least 30% German heritage that we use as our baseline treatment definition, 58 PUMAs with at least 40% German heritage, and 15 PUMAs with at least 50% German heritage. For each of the three 'High German' categories, we also include a p-value for whether the mean of each variable is statistically significantly different from the mean of the control PUMAs.[6]

Treated PUMAs have much higher rates of German heritage by definition. They are also much more likely to speak German as their main language at home, although these rates are low overall. The groups earned roughly similar wages, have similar levels of education, and are equally likely to be veterans. Residents of 'High German' PUMAs are slightly older, are less likely to be in poverty, and are more likely to be white. They are also slightly less likely to report having trouble with vision, which can impact driving. 'High German' PUMAs also have slightly more fatal accidents and total fatalities over our sample period of May through July of 2002. Our identification strategy does not require treatment and control PUMAs to be identical: Differences will only be a threat to our strategy if they are correlated with specific shocks to traffic accidents on the seven days when the German World Cup team is playing.

Figure 1 displays a map of our treatment assignment by PUMAs. The Eastern Time Zone region is in light grey because it is dropped from our main specifications; control regions appear in darker grey, while treated counties appear in shades of blue. Darker shades of blue indicate higher shares of German ancestry. German heritage is strongest in the upper Midwest, particularly in Wisconsin, Minnesota, North and South Dakota, Iowa, and Nebraska, with some treated areas also showing up in Montana, Wyoming, Colorado, Kansas, and Missouri.

4. Methodology

4.1. Motivation from the raw data

The basic idea of our methodology is to compare accidents across "high-German" PUMAs in the days before and after a German World Cup game to similar changes in "low-German" PUMAs over those same days. If individuals of German ancestry are more likely to watch German games and lose sleep, we anticipate observing spikes in accidents, particularly in areas with higher concentrations of German fans following German games.

Figure 2 illustrates this pattern in the raw data. It shows the mean fatal car accidents per day for very high-German percentage PUMAs (>50%) vs low-German percentage (<30%) PUMAs

[5] We demonstrate that our results are robust to the inclusion of PUMAs on ET, though, as expected, this decreases the size of our point estimates.

[6] Appendix Figure A.5 displays a bar graph showing the number of total PUMAs with different levels of German heritage in our analytical sample. Of the 1,041 total PUMAs in our dataset, 140 have 5% German heritage or less, 221 have 5-10%, 385 have 10-20%, 163 have 20-30%, 74 have 30-40%, 43 have 40-50%, and 15 PUMAs have more than 50% German heritage.

during the 2002 World Cup, which ran from May 31st to June 30th, and the days immediately before and after. The dashed vertical lines in the graph align with the date of each German game. On five of the seven German game days, there is a substantial spike in fatal accidents in the high-German PUMAs. These spikes are largest for the most important games, including the first German game, which it won 8-0 against Saudi Arabia on June 1, as well as the first knockout round game (June 15), the quarterfinal (June 21), the semifinal (June 25), and the final (June 30). Interestingly, there are no spikes on the final two group games, which may be because these games were of lesser significance, given Germany's opening match rout of Saudi Arabia.[7] Appendix Figures A.4 and A.3 recreate Figure 2 with thresholds of 30% and 40% for a PUMA to be classified as 'high-German', and the spikes on fatal crashes on important German World Cup matchdays appears in both of these groups as well.

4.2. Regression methodology

To formalize these patterns, we use a standard regression framework to estimate whether the difference between the crash rates in the treated versus control counties on the seven dates with German World Cup matches is larger than the average difference across these groups throughout May, June, and July. We estimate models of the form:

$$Accidents_{pd} = \beta_0 + \beta_1 GermanMatch_d \times HighGerman_p + \delta_p + \gamma_d + \epsilon \tag{1}$$

where $Accidents_{pd}$ is the number of fatal car accidents for PUMA p on day d. $GermanMatch_d$ is an indicator for whether there was a German World Cup match during the early morning hours of day d, and $HighGerman_p$ is an indicator variable that PUMA p has a German heritage above our threshold criteria. In our baseline model, we use the threshold of 30% German to assign PUMAs to $HighGerman_p = 1$, though we also report specifications with the threshold at 40% and 50%. The key coefficient is β_1 and measures the impact of late-night World Cup games on car accidents in PUMAs that are most likely to have been watching the game relative to other PUMAs. δ_p and γ_d are PUMA and date fixed effects, respectively, which control for any time-invariant differences across treated and control groups, as well as any day-level effects (e.g., weekends, holidays). Throughout, we cluster standard errors by PUMAs.

Our identifying assumption is similar to a standard difference-in-difference parallel trends assumption: There must be no other reason why fatal car accidents are higher in *HighGerman* PUMAs on the days of German World Cup matches other than the World Cup games themselves. We discuss this assumption in more detail in our robustness section.

[7] If two teams are tied on points after three games, the first tiebreaker is overall goal differential, so Germany's massive 8-0 win in their first game made it highly likely that they would qualify for the knockout round of the tournament. Germany would go on to tie Ireland 1-1 on June 5th before eventually beating Cameroon 2-0 on June 11.

5. Results

Table 1 shows the results from estimating Equation (1). The first three columns use all seven German matchdays as treatment days, and iteratively use higher percentage cutoffs for whether a PUMA is classified as *HighGerman*.[8] The second group of three columns repeats this process, instead focusing only on 'big games:' the opening match plus each of the knockout round matches.

The estimate in column 1 indicates that on German World Cup matchdays, PUMAs with more than 30% German heritage experience .0238 additional fatal car accidents (p-value=.010). Across the 163 treated PUMAs, this translates to roughly 3.88 extra fatal accidents per matchday, and a total of 27.16 additional fatal accidents over the course of the World Cup. When the threshold is increased to 40%, the point estimate increases to .0376 (p-value=.007), translating to an additional 2.73 fatal accidents per matchday across the 74 treated PUMAs, or 19.1 additional crashes total. When focusing on the 15 PUMAs with more than 50% German heritage, the point estimate jumps to .1052 (p-value=.000). This translates to an additional 1.56 crashes per matchday, or 10.97 extra crashes across the World Cup across just these 15 PUMAs.

As expected, the point estimates are larger when focusing only on the five most important German matches. For PUMAs with at least 30% German heritage, the point estimate is .0291 (p-value=.011), which increases to .0465 (p-value=.011) and to .153 (p-value=.000) when we increase the threshold to 40% and 50%.

5.1. Mechanisms and heterogeneity

In this subsection we explore possible mechanisms. Our primary suspected mechanism is sleep loss, but an equally plausible alternative is that people consumed alcohol while watching games, which led them to be more likely to get into a crash.

To test between these alternatives, the top of Figure 3 reports estimates of our main specifications separately for crashes that did and did not involve alcohol. FARS records drivers as drinking if they have a positive blood alcohol concentration (BAC) result from a blood or breath test or if the police report alcohol involvement. The first row of Figure 3 reproduces our baseline results on the full sample. The second row shows results for non-drunk accidents. The three estimates are similar, though slightly smaller than the baseline estimates and a test for whether each is equivalent to the main estimate fails to reject the null hypothesis. The third row shows results for drunk driving estimates. Estimates are close to zero and statistically distinct from our main estimates. This pattern implies the increase in fatal crashes we find in our main results is driven by accidents that do not involve alcohol.

The fourth and fifth rows split our data by gender. Since most crashes involve at least two drivers, for each gender we keep all crashes involving at least one driver of that gender. The

[8] Whenever we increase the threshold, we drop all observations that are above 30% but below the new threshold, so that we are not counting any PUMAs as treated in some specifications and controls in others.

coefficients suggest that our baseline estimated increases in accidents are from crashes involving male drivers. This is consistent with these effects being driven by the World Cup: According to a recent Morning Consult poll, men are roughly three times more likely to describe themselves as an 'avid' or 'diehard' sports fan, consistent with our findings (Consult, 2023). Rows six and seven look at accidents involving any driver over 60 or under 20 years old. All estimates for these age groups are precise nulls: Our estimated increases in fatal crashes come from accidents involving 20-60 year-olds. Rows eight and nine show results separately for counts of crashes with and without a child passenger under 15 years old. This proxies for whether drivers involved in crashes are parents. Our results are driven by accidents not involving any children.

The next two rows of Figure 3 split our data by whether crashes occurred when driving conditions were 'clear' or not. 94% of all accidents occurred in 'clear' conditions during our sample window of May-July 2002, so we would expect our results to be from accidents occurring under clear conditions. If this were not the case, it would raise concerns that the 'High-German' PUMAs experienced particularly bad weather on the same days as the German World Cup matches, driving our results. Figure 3 shows that, as expected, our baseline estimated increases are almost entirely accidents which occur in 'clear' weather conditions.

Finally, we split the data by the time of day of each accident. We investigate whether German World Cup matchdays are associated with more accidents during the morning hours (12AM-8AM), daytime (8AM-4PM), or evening (4PM-12AM) hours. The final three rows of Figure 3 display separate estimates for accidents in each of these windows. Crashes appear to have increased in both the morning and evening hours, with similar estimates in both size and significance for each. Both groups of estimates are about half as large as the main estimates on all accidents. Morning crashes could be attributed to either sleepy drivers on the road headed somewhere to watch the game, or driving back home or into work after the game had finished. Evening crashes are consistent with sleepy drivers getting into accidents on the way home from work.[9]

In order to look for potential spillovers from one day to the next, Appendix Figure A.7 displays estimates from models with additional treatment indicators for the two days leading up to each match, as well as the two days following each match. In contrast to some findings on the effect of DST transitions (e.g., Smith, 2016), we only find effects directly on the day of the match in question. Across specifications, only the coefficient on the matchday itself is statistically different than zero. One possible explanation for our lack of spillovers could be that the sleep loss incurred from waking up very early for a game could be more salient than the loss of sleep from DST. Individuals may respond by making an extra effort to get to bed early the following night to catch up, especially when they expect to incur another loss of sleep in a few days.

[9] Appendix Figure A.6 repeats the estimates from 3, only focusing on the five 'biggest' German World Cup games, instead of including estimates for all games, and the results are qualitatively similar to Figure 3.

5.2. Robustness

Figure 4 displays estimates from a series of robustness checks to address several potential concerns with our identification assumptions. We include the estimates from the first three rows of Table 1 as a baseline for comparison in the first row of this figure. The next row includes PUMAs in Eastern Time, which we excluded in our main specifications. When we include ET, the estimates are somewhat attenuated, which makes sense since we believe these PUMAs are treated with lesser intensity. The following two rows test our results' robustness to widening and narrowing the sample window, which might alter our estimates if there was important differential seasonality across the treated and control PUMAs throughout the year.[10] Our estimates are stable when we include control day observations for the whole year of 2002 or when we narrow the window to just June of 2002. Next, in the fifth row of the figure, we replace the number of fatal car accidents on the left-hand side of equation (1) with the total number of fatalities. The coefficients are nearly identical to the estimates from our main specifications.

Next, we test whether our results are robust to the functional form of our outcome variable, the number of fatal crashes on a PUMA-day. This variable could be right-skewed, complicating the interpretation of our results. Appendix Figure A.8 illustrates this concern by displaying a histogram of our dependent variable from our main analytical sample. The vast majority of observations are either zeroes or ones, making up 99.76% of our sample. In order to ensure that the small right tail of accidents is not driving our results, we replace the dependent variable with a binary outcome for whether there was any fatal accident in a given PUMA-day. The sixth row of Figure 4 shows this result is nearly identical to our main specifications. A related concern is that our results could be driven by an outlier PUMA. Appendix Figure A.10 displays results of a 'leave-one-out' analysis, where we reestimate our main specifications, iteratively dropping a single treated unit each time. The coefficient plots are all tightly clustered around our main estimates, implying that any particular treated PUMA does not cause our findings.

Because four of Germany's seven matches take place on a Friday, Saturday, or Sunday, there is concern that we could be picking up the effect of weekend spikes in fatal car accidents that differentially occur in high-German areas. To address this, we control for an indicator for whether an observation takes place on the weekend multiplied by an indicator for whether the observation is from a 'High-German' PUMA. The last column of Figure 4 displays estimates after including this control; they are virtually identical to our main estimates. Even within weekends in 'High-German' PUMAs, World Cup matchdays are especially likely to have fatal car accidents.

So far, we have argued that our estimates of increased fatal car accidents on German matchdays during the 2002 World Cup are due to sleep loss, but it is also possible that they could be due to the games themselves. Major sporting events have been shown to influence domestic violence (Card and Dahl, 2011; Cardazzi et al., 2022), hooliganism and other violent crime (Andres et al., 2023), and have even been shown to impact the decision-making of judges (Eren and Mo-

[10] Our baseline results uses May, June, and July as our estimation window.

can, 2018). To address this possibility, we use the 2006 World Cup as a placebo. The 2006 World Cup was held in Germany, and 'Die Mannschaft' once again made a deep run in the tournament, losing to the eventual champions Italy in the semifinal. The major difference from 2002 to 2006 is that none of the 2006 games were played during normal sleeping hours for US-based fans.[11]

The final row in Figure 4 displays estimates from our main specification, instead looking for increases in fatal accidents in 'High-German' PUMAs on German matchdays for the 2006 World Cup. All estimates are close to and statistically indistinguishable from zero, suggesting that our main findings are not simply due to the World Cup matches. Since the biggest difference between 2002 and 2006 for US-based German fans was the timing of the matches, we believe the most likely mechanism behind our results is sleep loss associated with watching early morning games.

One remaining concern is that the accident increases we find on German World Cup matchdays are a product of chance, and that the normal variation in accidents from day-to-day and week-to-week happens to line up with the dates of Germany's games. To further address this possibility, we randomly assign treatment days in order to see how often estimates of the magnitude of the ones we report above can happen by chance. We begin with our main analytical sample, which includes May, June, and July, and drops all PUMAs on Eastern Time (ET). Because Germany's actual treated days are all in June, we drop observations from June and add August in order to keep a similar sample size. For each iteration, we randomly select seven days in July to be 'German matchdays' and five of those seven days to be 'Big German Matchdays'. We then run each of the six specifications from Table 1 and save the coefficients. We repeat this process 1,000 times.

Appendix Figure A.9 shows the distributions of these 1,000 placebo estimates and a vertical line marking our actual point estimate from Table 1. Across all six specifications, our point estimate is larger in magnitude than at least 98.5% of the placebo specifications, and is larger than 99% of them in five of the six cases. The implied p-values for the three specifications including all German games and progressively larger thresholds are .006, .014, and .006, while the p-values for the specifications on only the most important games are .007, .008, and .001, respectively. This simulation suggests that our results are very unlikely to emerge by chance.

6. Conclusion

This paper shows that acute, recreation-driven sleep loss can have serious public health consequences. Using the unique timing of the 2002 FIFA World Cup as a natural experiment, we find that PUMAs with a high concentration of residents with German ancestry, who are more likely to be watching Germany's late-night matches, experienced significant increases in fatal car accidents on matchdays. Our effects are large, robust across model specifications, and not attributable to alcohol consumption or bad weather, which strengthens the conclusion that sleep deprivation

[11] For fans in Central Standard Time zone, the 2006 games started at either 8:00 a.m., 11:00 a.m., or 2:00 p.m., meaning that only individuals who typically sleep past 8:00 a.m. would have experienced any sleep loss during the 2006 World Cup.

is the causal mechanism. Our placebo test using the 2006 World Cup, where Germany performed similarly well but where none of the matches took place during regular sleep hours for American viewers, further supports this interpretation.

Using our estimate on the number of fatalities, late-night World Cup matches were associated with an increase of 28.8 deaths on the days following matches. Using the Department of Transportation's 2002 guidance on the Value of a Statistical Life (VSL) of $3 million USD, this translates to a total cost of $86.5 million, while a similar loss of life would cost 394.6 million using the 2024 VSL of 13.7 million (USDOT, 2024).

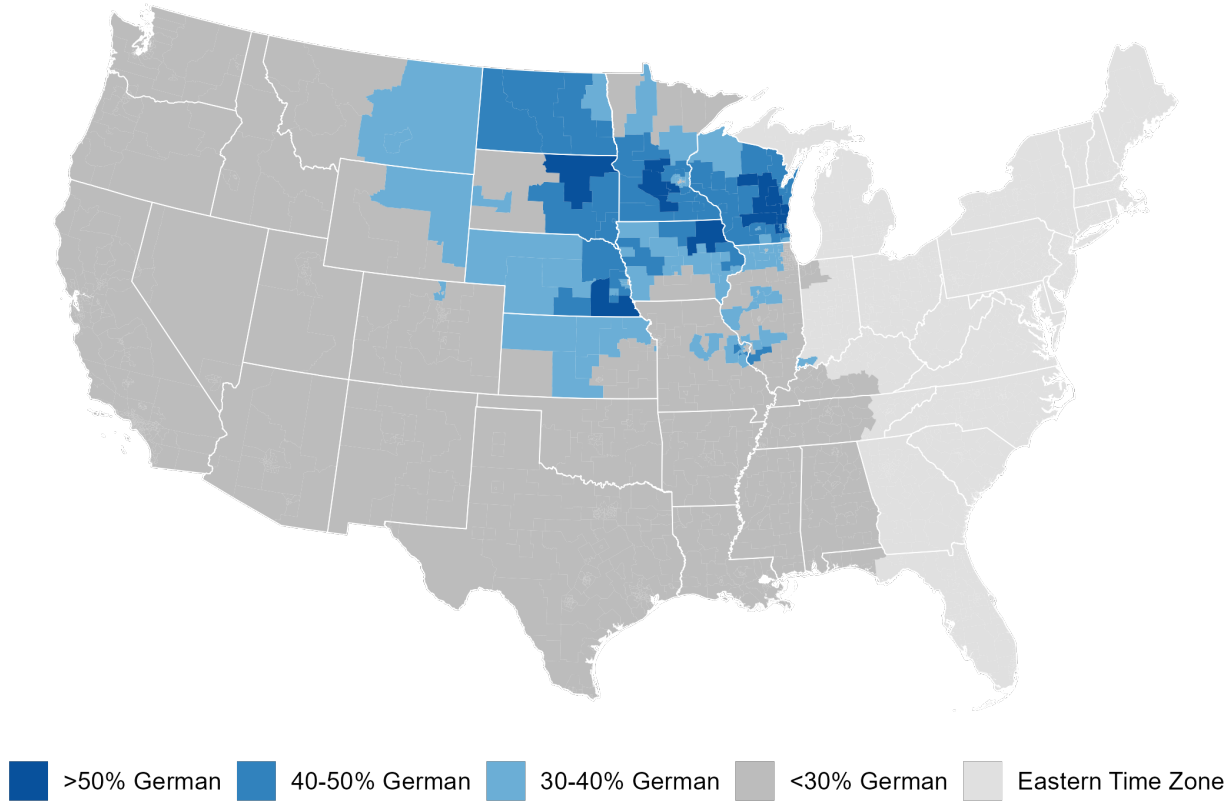
Our findings have broader implications for understanding the externalities of sleep loss, especially when it is voluntary and driven by leisure decisions rather than by Daylight Savings Time, sunset times, or school start times. These findings suggest that leisure decisions like watching international sports events can yield serious unintended consequences when they interfere with sleep. Our results suggest that policy responses like increased policing around late-night events or public service announcements during games may mitigate potential harms. More broadly, we might expect that similar impacts emerge from other recreation activities, like late-night socializing or gaming. We hope that this research motivates future exploration of these risks.

Table 1 — The Effect of Late-Night German World Cup Match on Fatal Car Accidents in Heavily German PUMAs

	Dependent Variable: Fatal Car Accidents per Day per PUMA					
	All German Games			*Big German Games*		
	30%	40%	50%	30%	40%	50%
German x Matchday	0.0239*	0.0376**	0.105***	0.0292*	0.0465*	0.153***
	(0.00923)	(0.0140)	(0.0257)	(0.0115)	(0.0182)	(0.0323)
Observations	96,784	89,884	85,928	96,784	89,884	85,928
Mean of Dep. Var.	.060	.068	.074	.060	.068	.074

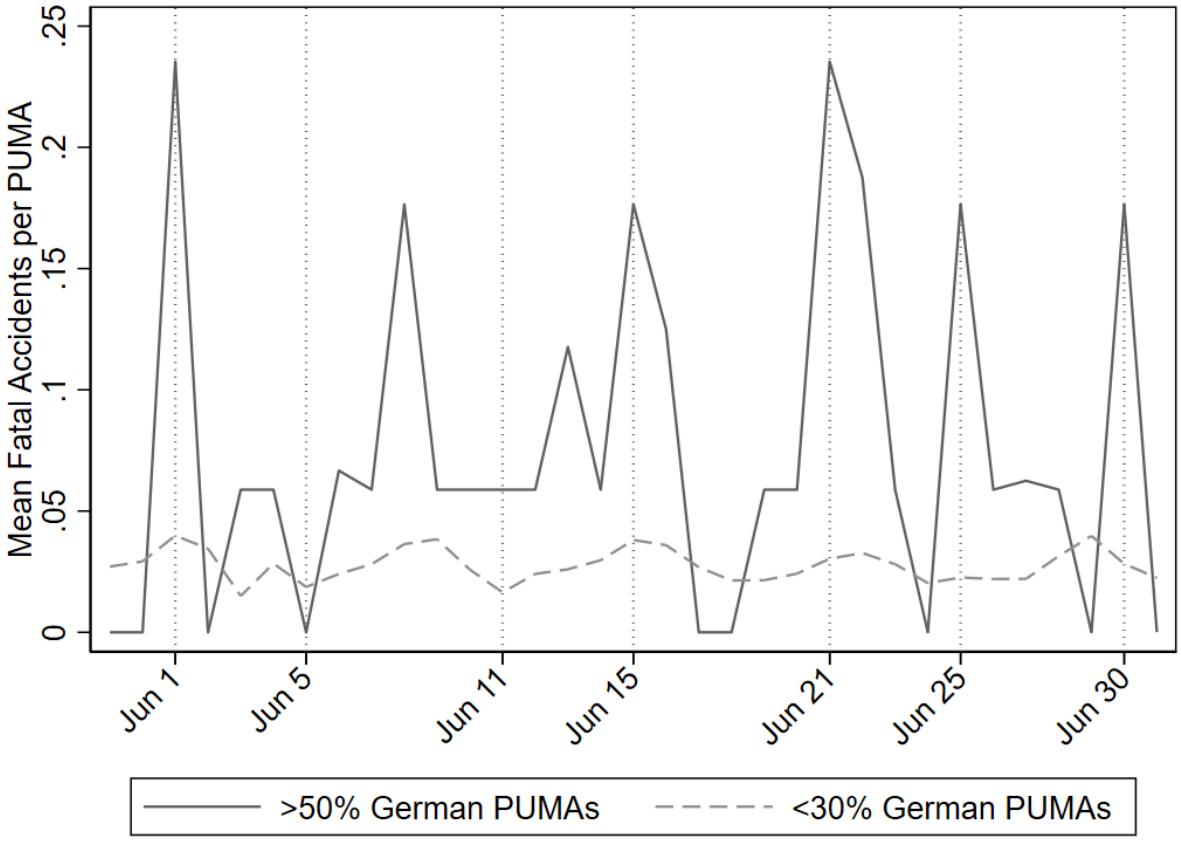
Note: This table displays estimates of the effect of late night German World Cup games on fatal car accidents in heavily German Public Use Microdata Area (PUMAs), excluding those on Eastern Standard Time. The analytical sample includes daily observations for 1,038 PUMAs for May, June, and July, which includes the 2002 World Cup which ran from May 31-June 30. The coefficient of interest is an interaction term for whether the daily observation occurred on a day in which the German national team played in a World Cup game and whether the PUMA that is observed has a high percentage of German heritage. The first column counts all PUMAs with at least 30% German heritage as being treated, with the second and third rows increase this threshold to 40% and 50%, respectively. The first three columns estimate this effect across all seven World Cup matches, while the second three columns repeat this exercise on only the five most important matches, which include the German team's first game, along with all of their knockout round games. * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 1 — Map of Treatment Status by German Heritage



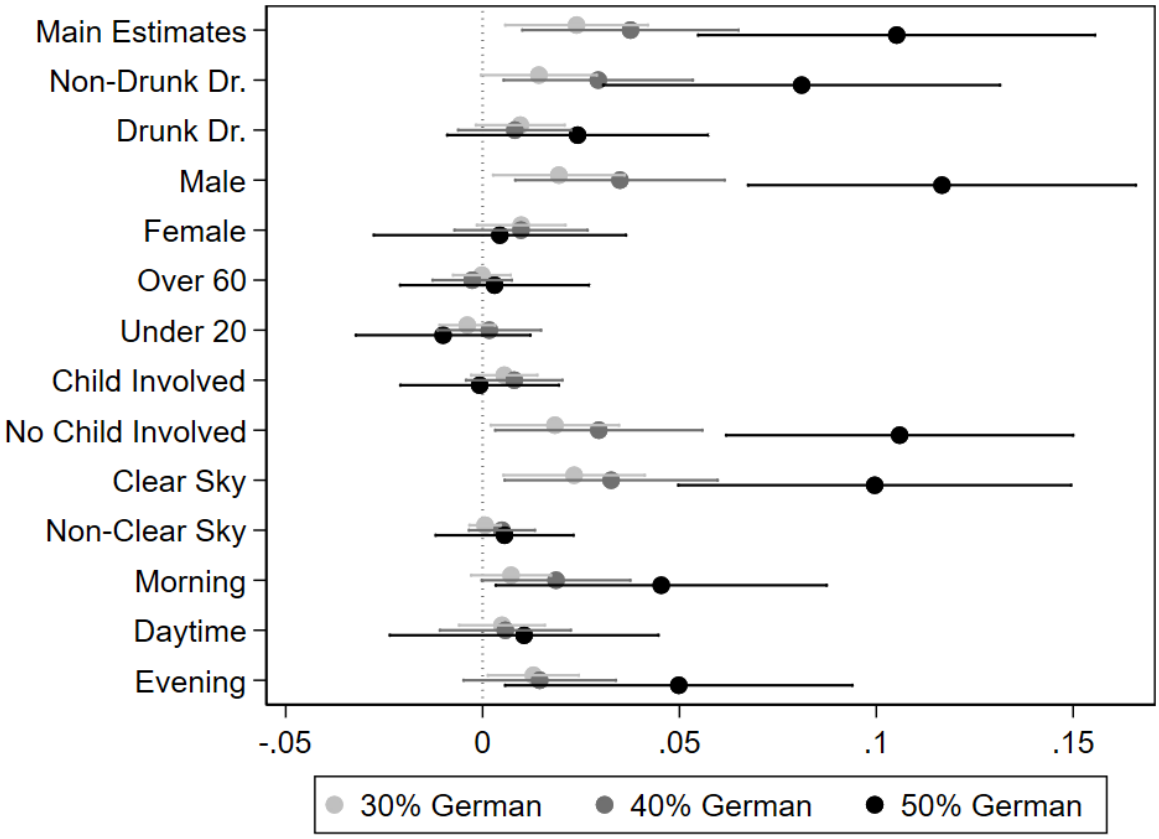
Note: This figure displays US PUMAs mapped by treatment status, using data from the 2000 5% Census. PUMAs are mapped to time zones using their centroids. We drop all PUMAs which observe Eastern Time (ET), and separate PUMAs by whether they have less than 30% German heritage, 30-40% German heritage, 40-50% German heritage, or 50% German heritage.

Figure 2 — Mean Fatal Car Accidents for High vs. Low-German PUMAs, June, 2002



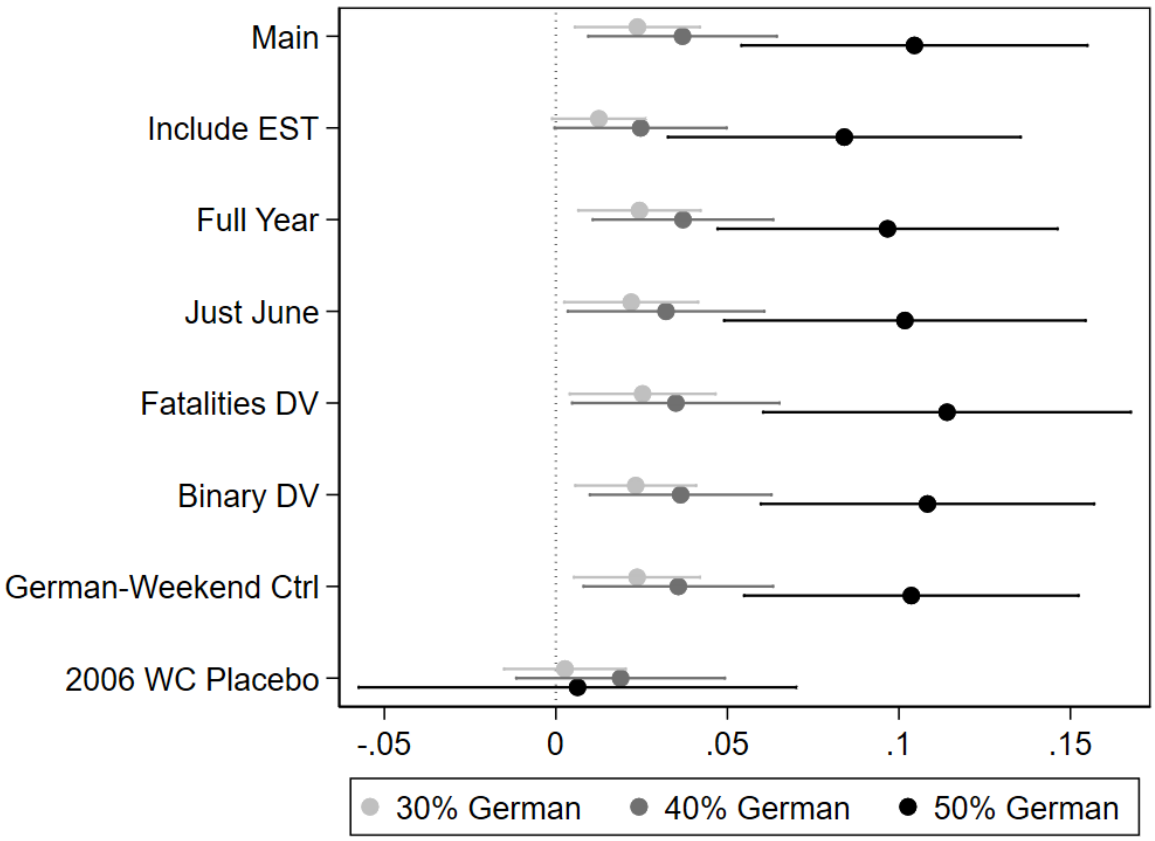
Note: This figure displays the mean fatal accident rate surrounding the June 2002 World Cup for PUMAs with greater than 50% of their population descending from Germany versus PUMAs with less that 30% of their population descending from Germany, not including PUMAs on Eastern Time. This graph combines fatal accident rates from the Fatal Accident Reporting System (FARS) with heritage data for each PUMA from the 2000 5% Census. Each German match day is highlighted with a vertical line.

Figure 3 — Coefficient Estimates of the Effect of Late Night German World Cup Matches on Fatal Car Accidents in PUMAs with High German Heritage - By Alcohol Status, Time of Day, Gender, and Weather



Note: This figure displays coefficients estimates of the effect of late-night German World Cup matches on fatal car accidents in PUMAs with high German heritage, broken down by characteristics of the crash. From top to bottom, the first three estimates are from our main specifications in Table where we count all seven German World Cup games as treated as a baseline for comparison. Estimates for 30% German PUMAs are displayed in light gray, followed by 40% PUMAs in dark gray and 50% PUMAs in black. We then display the same estimates for crashes not involving a drunk driver, followed by estimates for crashes involving a drunk driver, crashes involving any male driver, any female driver, any driver over 60, any driver under, crashes involving a child passenger, and crashes not involving a child passenger. Finally, we display estimates based on whether the accident occurred during 'Clear' conditions or not, and for for accidents that occurred in the morning (12AM-8AM), in the daytime (8AM-4PM) and in the evening (4PM-12AM).

Figure 4 — Coefficient Estimates of the Effect of Late Night German World Cup Matches on Fatal Car Accidents in PUMAs with High German Heritage - Robustness Checks



Note: This figure displays coefficients estimates of the effect of late-night German World Cup matches on fatal car accidents in PUMAs with high German heritage, with several alterations to our main specification to test for robustness. From top to bottom, the first three estimates are from our baseline specifications in Table using all seven German World Cup games as treated. Estimates for 30% German PUMAs are displayed in light gray, followed by 40% PUMAs in dark gray and 50% PUMAs in black. Next, we include PUMAs in the Eastern Timezone. In the third row, we use the full year of 2002 as our sample. In the fourth row, we restrict our sample to June 2002. In the fifth row, we use the total number of fatalities (instead of accidents) as the dependent variable. In the sixth row, we replace the number of fatal accidents with a binary indicator for whether there was a fatal accident in a given PUMA on that day. In the seventh row we include a separate control for whether an observation takes place on the weekend in a high-german PUMA. Finally, in the eighth row, we include a placebo specification using data from the 2006 World Cup.

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A. Online Appendix (Not for Publication)

Table A.1 — Summary Statistics for 'High-German' and 'Low-German PUMAs - 2000 Census and 2002 FARS Data.

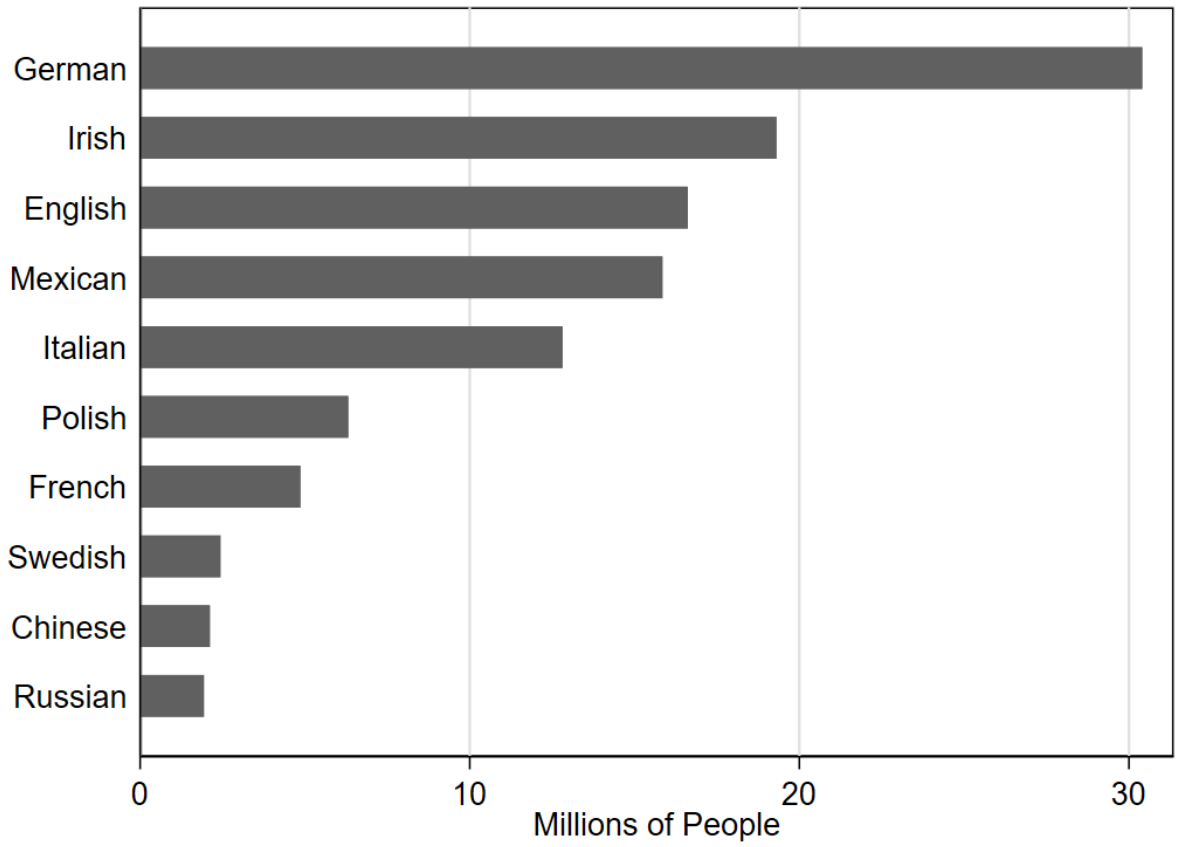
	Control	*30% German*		*40% German*		*50% German*	
	Mean	Mean	P-value	Mean	P-value	Mean	P-value
German	.130	.402	.000	.473	.000	.534	.000
Speak German	.0046	.0093	.000	.0125	.000	.0162	.000
Wage Income	19,436	20,368	.157	19,104	.728	20,506	.564
Age	35.04	36.74	.000	36.93	.000	36.93	.017
Male	.491	.494	.030	.497	.002	.498	.062
Years of Ed.	11.21	11.45	.000	11.32	.268	11.32	.575
Poverty	.125	.064	.000	.062	.000	.053	.000
Veterans	.092	.100	.001	.098	.073	.096	.547
Poor Vision	.037	.033	.000	.033	.001	.031	.028
White	.703	.936	.000	.956	.000	.963	.000
Black	.108	.017	.000	.008	.000	.005	.013
Hispanic	.190	.026	.000	.017	.000	.015	.001
Daily Accidents	.055	.060	.187	.068	.034	.074	.124
Daily Fatalities	.062	.068	.287	.079	.035	.086	.128
Distinct PUMAs	906	132		58		15	

Note: This table displays summary statistics for our treated and control counties using data from the 2000 5% Census and the 2002 Fatal Accident Reporting System, excluding all PUMAs in the Eastern Standard Timezone. We include means for our 906 control PUMAs which have less than 30% of their population with German heritage, the 132 PUMAs which have greater than 30% German heritage, the 58 PUMAs with greater than 40% German heritage, and the 15 PUMAs with greater than 50% German heritage. We also include the average number of daily fatal car accidents and the average number of daily traffic fatalities during our sample window of May through June, 2002.

Figure A.1 — Articles and Headlines about Sleep Loss and the 2002 World Cup

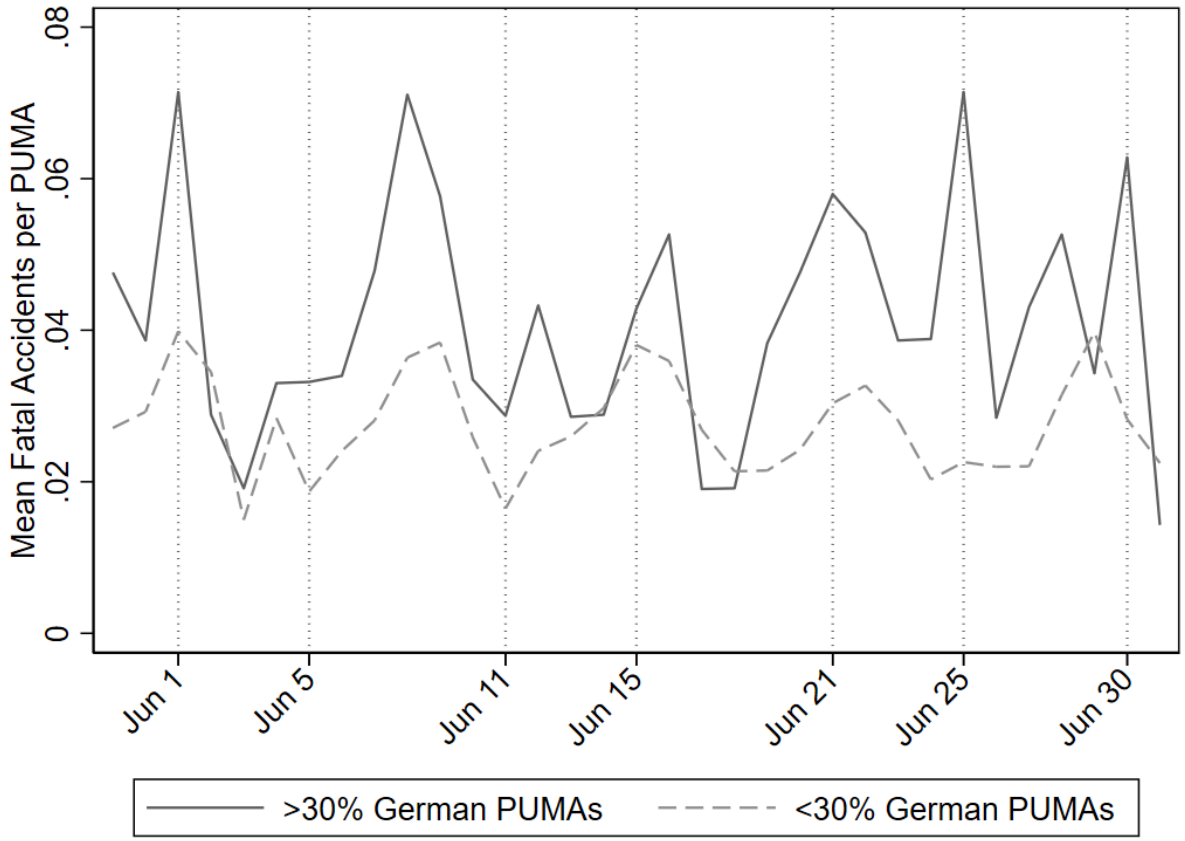
Note: This figure displays a sample of articles and headlines from US newspapers about sleep loss during the 2002 World Cup. Articles were found on newspapers.com using the search term "sleep world cup" filtered for the year 2002.

Figure A.2 — Number of Americans in the 2000 Census Who Claim Heritage from Countries Which Participated in the 2002 World Cup.



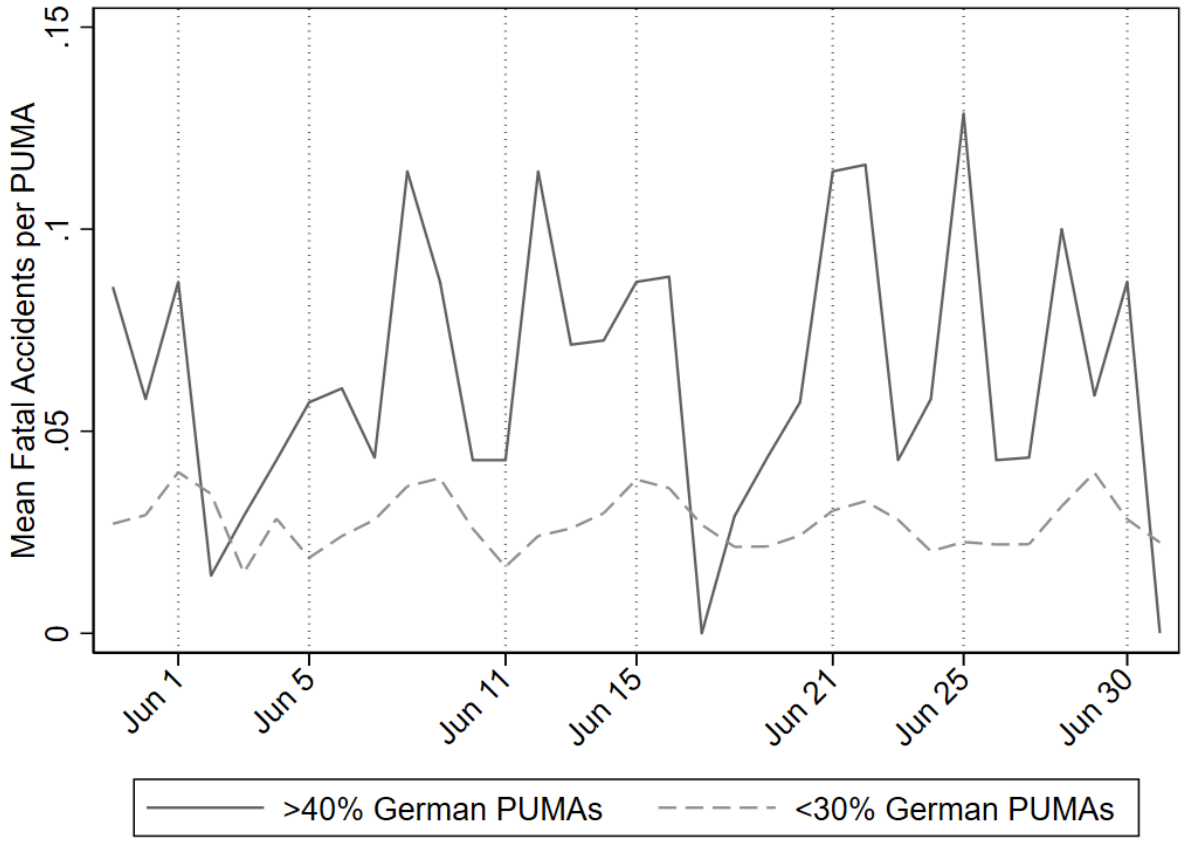
Note: This figure displays the number of American residents who report having ancestry in each of the ten countries which participated in the 2002 World Cup who having the highest number of American residents hailing from their nation.

Figure A.3 — Mean Fatal Car Accidents for High vs. Low-German PUMAs, June 2002 - Threshold of 30% German



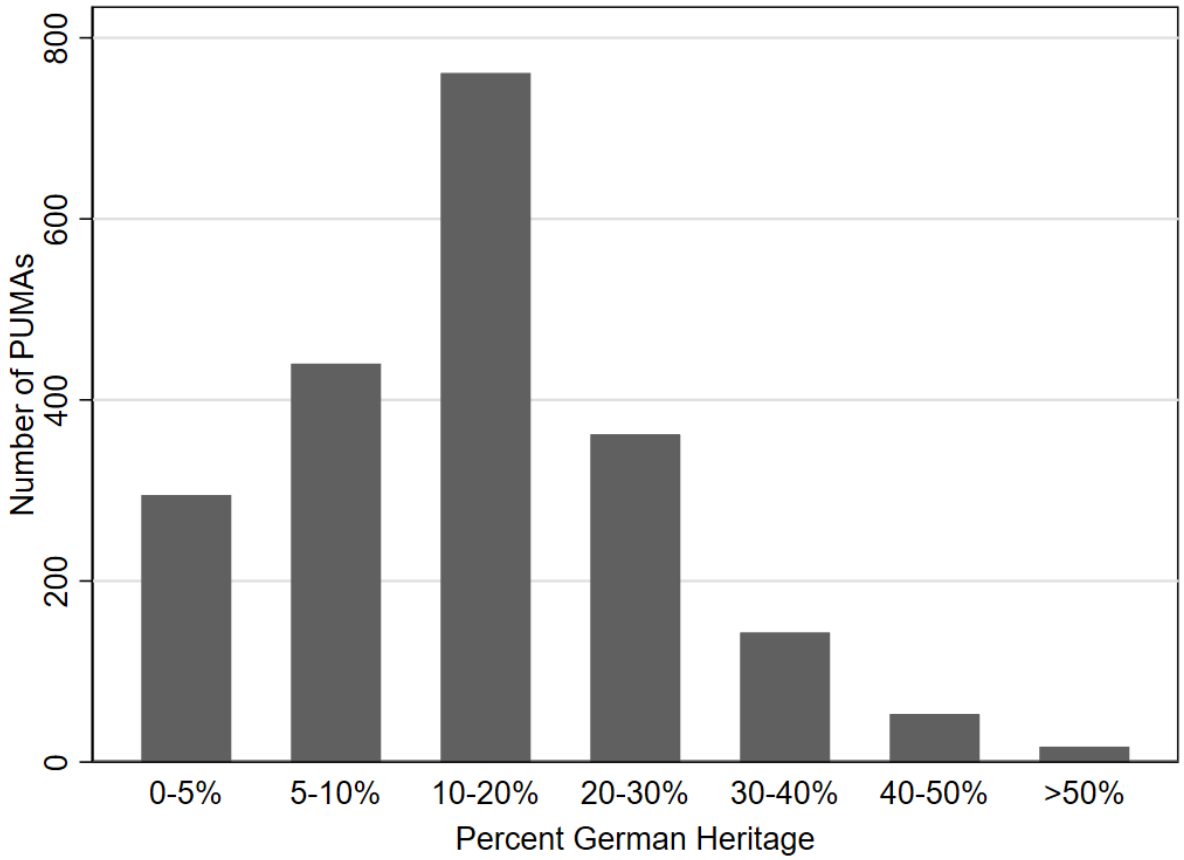
Note: This figure displays the mean fatal accident rate surrounding the June 2002 World Cup for PUMAs with greater than 30% of their population descending from Germany versus PUMAs with less that 30$ of their population descending from Germany, not including PUMAs on Eastern Time (ET). This graph combines fatal accident rates from the Fatal Accident Reporting System (FARS) with heritage data for each PUMA from the 2000 5% Census. Each German match day is highlighted with a vertical line.

Figure A.4 — Mean Fatal Car Accidents for High vs. Low-German PUMAs, June 2002 - Threshold of 40% German



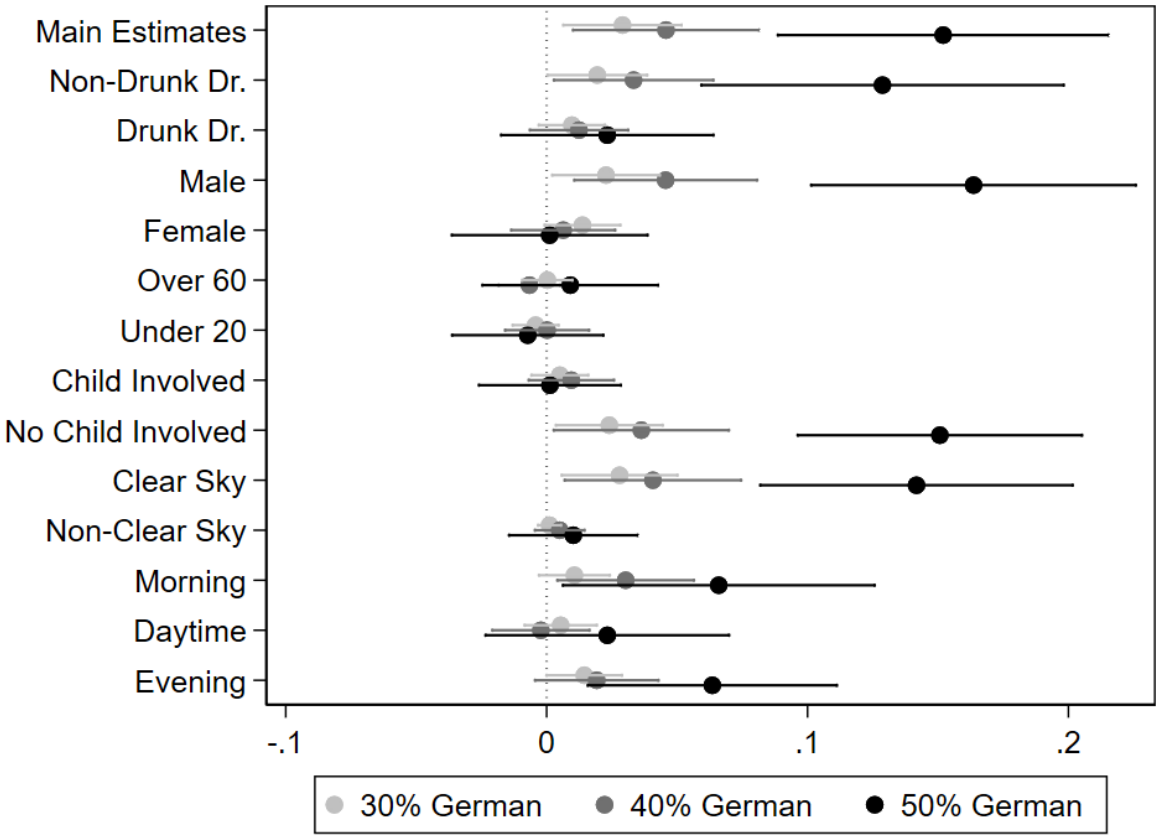
Note: This figure displays the mean fatal accident rate surrounding the June 2002 World Cup for PUMAs with greater than 40% of their population descending from Germany versus PUMAs with less that 30$ of their population descending from Germany, not including PUMAs on Eastern Time (ET). This graph combines fatal accident rates from the Fatal Accident Reporting System (FARS) with heritage data for each PUMA from the 2000 5% Census. Each German match day is highlighted with a vertical line.

Figure A.5 — Bar Graph of Number of PUMAs with Different Percentages of German Heritage - 2000 5% Census



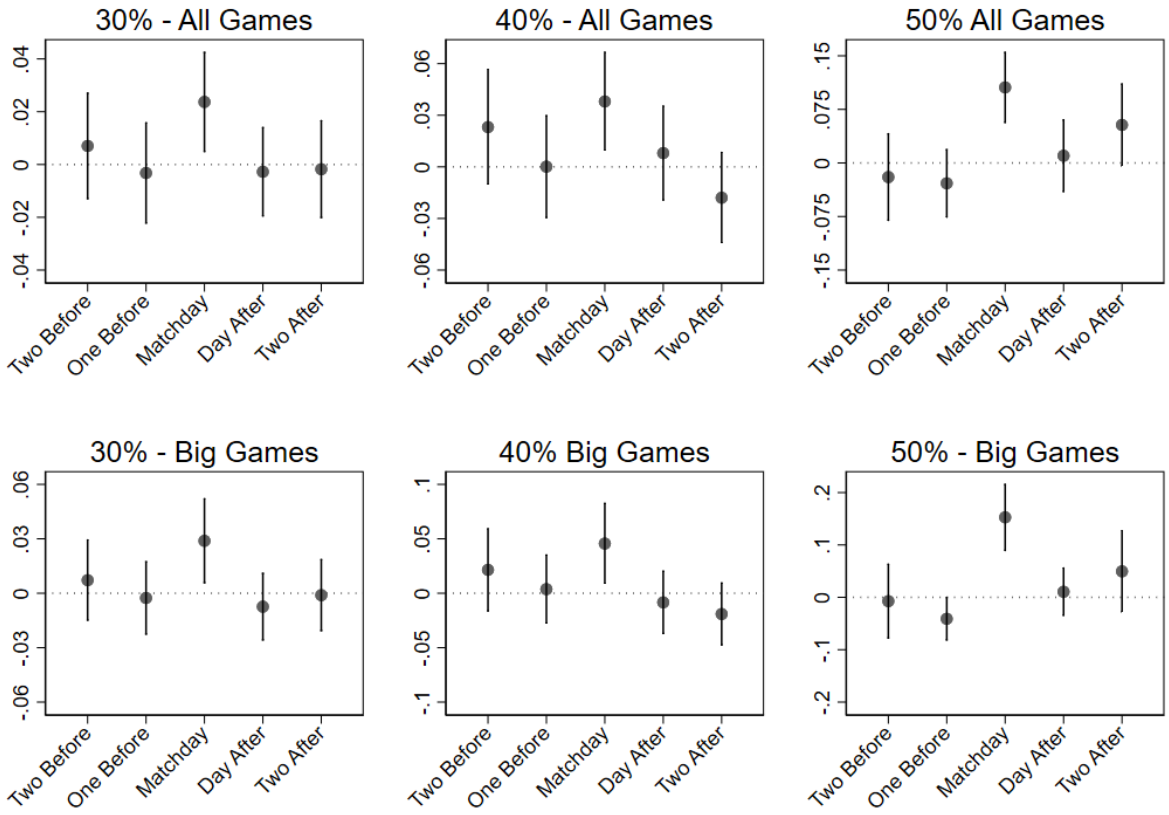
Note: This figure displays counts of the number of PUMAs in the United States with the percentage of German heritage in each of the labeled bins. There are 295 PUMAs with 5% or less, 440 with 5-10%, 760 with 10-20%, 362 with 20-30%, 143 with 30-40%, 53 with 40-50%, and 17 PUMAs with more than 50% German heritage.

Figure A.6 — Coefficient Estimates of the Effect of Big Late Night German World Cup Matches on Fatal Car Accidents in PUMAs with High German Heritage - By Alcohol Status and Time of Day



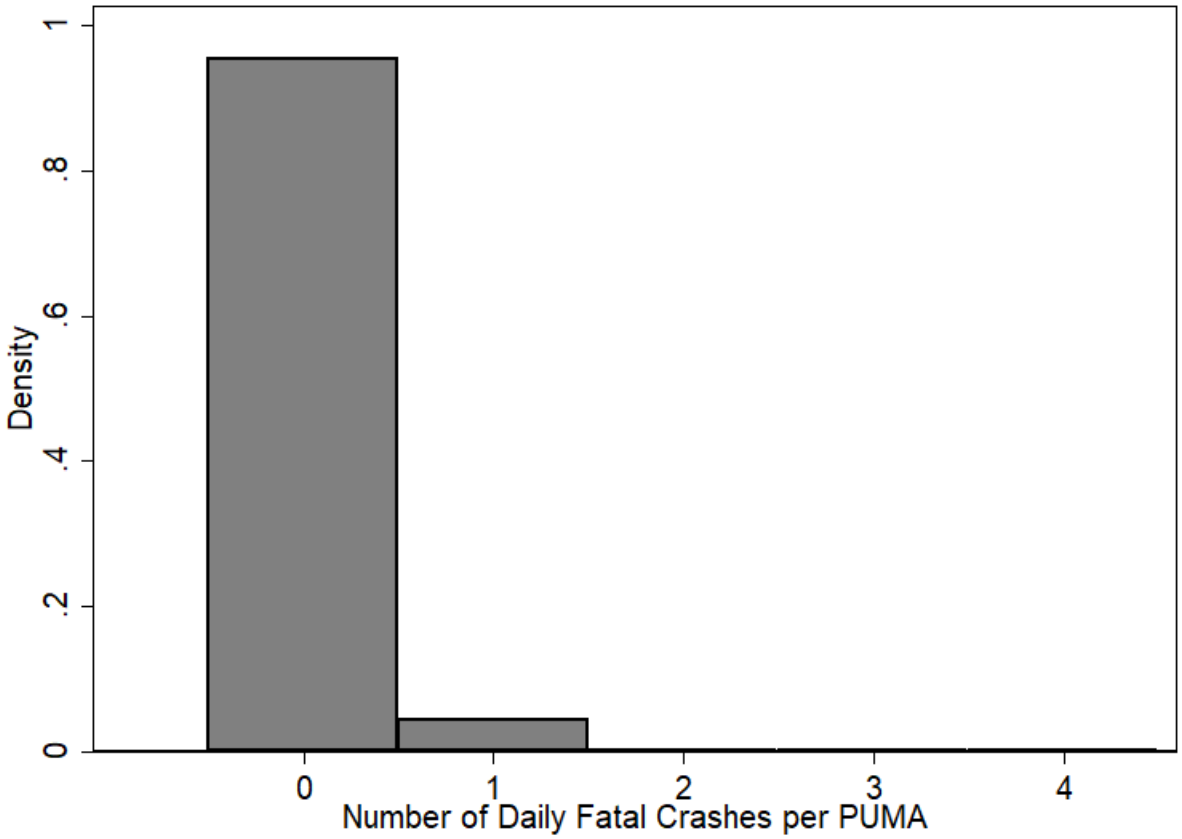
Note: This figure displays coefficients estimates of the effect of important late-night German World Cup matches on fatal car accidents in PUMAs with high German heritage, broken down by various characteristics of the crash. From top to bottom, the first three estimates are from our main specifications in Table where we count all seven German World Cup games as treated as a baseline for comparison. Estimates for 30% German PUMAs are displayed in light gray, followed by 40% PUMAs in dark gray and 50% PUMAs in black. We then display the same estimates for crashes not involving a drunk driver, followed by estimates for crashes involving a drunk driver, crashes involving any male driver, any female driver, any driver over 60, any driver under, crashes involving a child passenger, and crashes not involving a child passenger. Finally, we display estimates based on whether the accident occurred during 'Clear' conditions or not, and for for accidents that occurred in the morning (12AM-8AM), in the daytime (8AM-4PM) and in the evening (4PM-12AM)

Figure A.7 — Coefficient Estimates of the Effect of Big Late Night German World Cup Matches on Fatal Car Accidents in PUMAs with High German Heritage - Including Possible Spillover Effects onto Neighboring Days



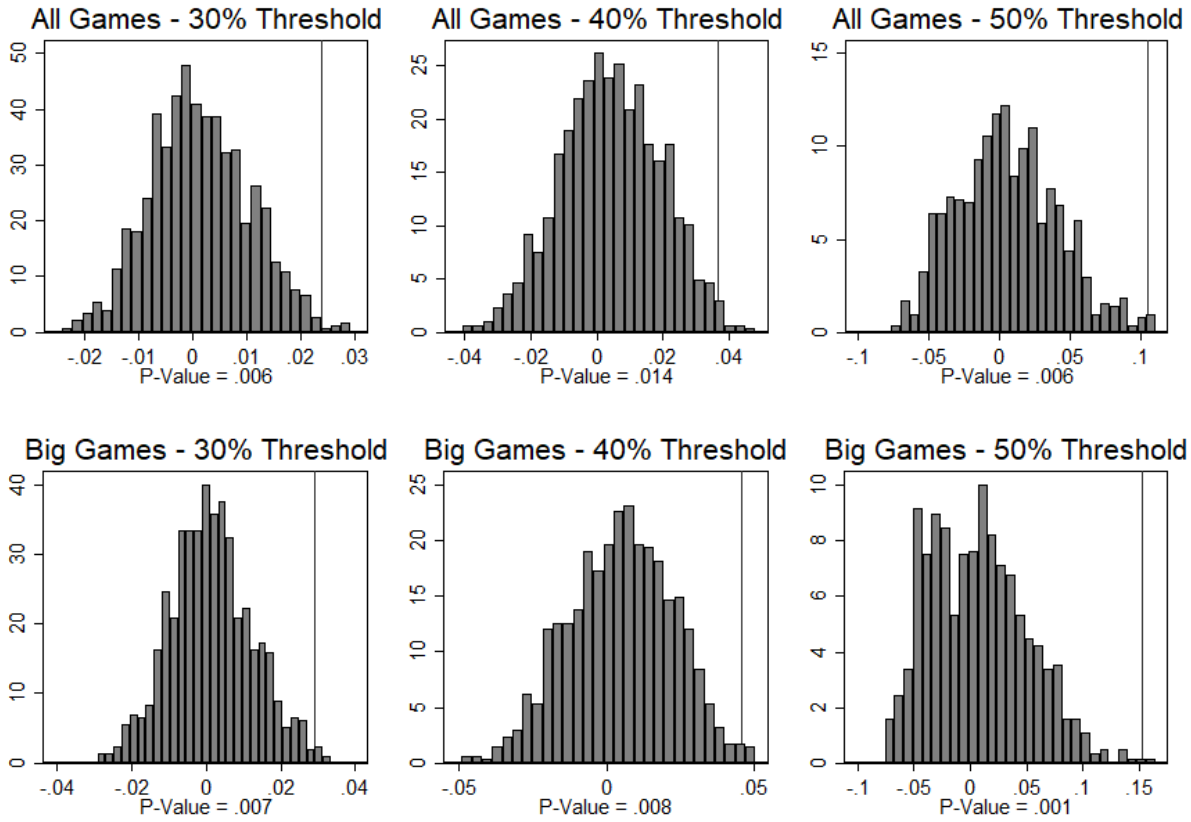
Note: This figure displays coefficients estimates of the effect of important late-night German World Cup matches on fatal car accidents in PUMAs with high German heritage, with separate estimates for each of the two days leading up each match, as well as the two days following each match.

Figure A.8 — Histogram of the Number of Daily Fatal Car Accidents per PUMA During May through July, 2002



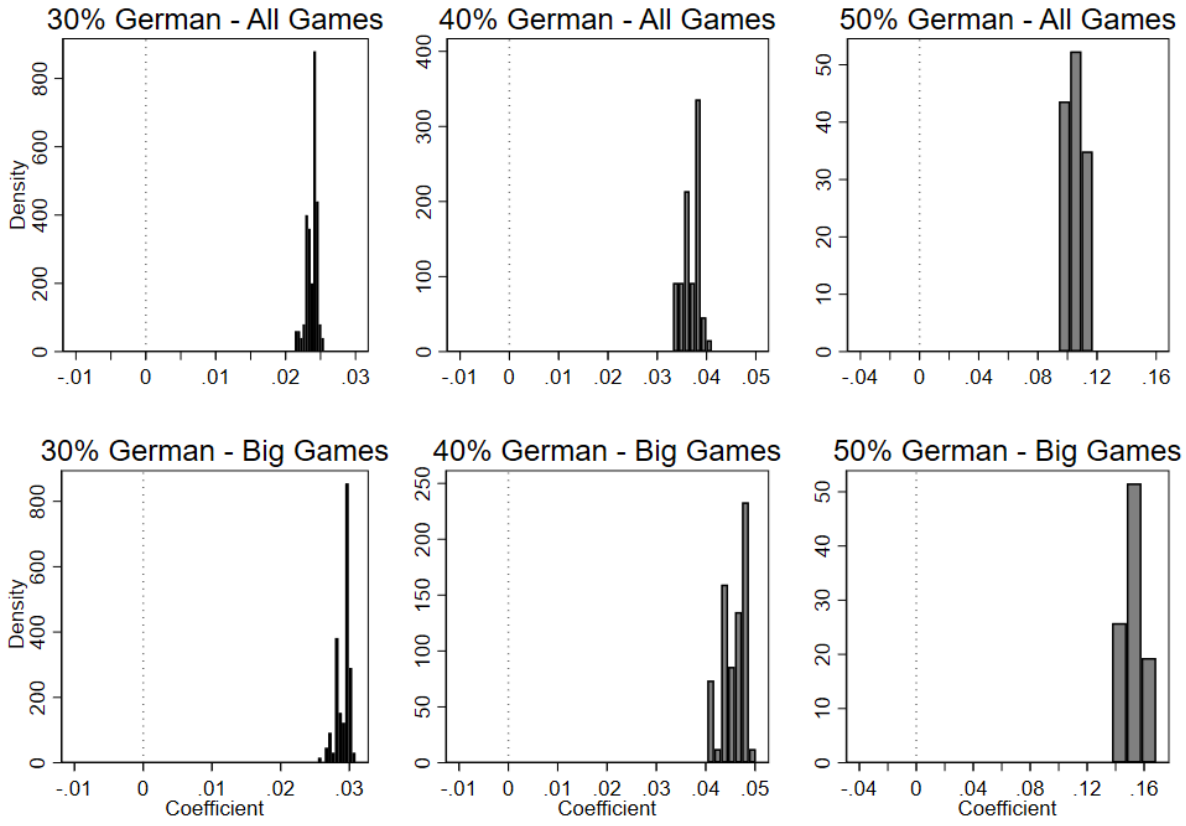
Note: This figure displays a histogram of the number of daily fatal car accidents per PUMA in the United States from May through July of 2002, using data from the Fatal Accident Reporting System (FARS). Of the 95,496 total observations in our analytical sample, 90,455 (94.72%) are zeroes, 4,814 (5.04%) are ones, 215 (0.23% are twos), 10 (.01%) are threes, and 2 (0.00%) are fours.

Figure A.9 — Placebo Simulation Distributions for Randomization Inference on the Effect of German World Cup Matches on Fatal Car Accidents in PUMAs with High German Heritage



Note: This figure displays distributions of the coefficient estimates from 1,000 placebo simulations. For each estimate, seven days in August of 2002 are chosen to be "German Matchdays", while five of these are chosen to be "Big German Matchdays". For each round, we run our main specification on these treatment days to see how often this process would return estimates as extreme as the ones we find in our main specifications.

Figure A.10 — Leave-One-Out Analysis Testing Robustness of the Effect of Late-Night German World Cup Matches on Fatal Car Accidents in PUMAs with High German Heritage



Note: This figure displays histograms of coefficient estimates from specifications where we estimate the effect of late-night German World Cup matches on fatal car accidents in PUMAs with high German heritage.Each specification 'leave outs' a single treated unit.