

## Preview

# Where are all the guns? Modeling firearm ownership in the United States

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Firearm possession rates across the United States are important for policy makers and the public alike, yet reliable data are notoriously hard to come by. In this issue of *Patterns*, Barak-Ventura et al. develop a model to estimate state-level firearm ownership and analyze the causal relationships among firearm possession, the occurrence of mass shootings, and media coverage.

Gun-related violence is widely considered a major threat to public health and safety in the United States, with a number of 45,222 firearm-related deaths reported by the Centers for Disease Control and Prevention in 2020. Political proposals to contain this public health crisis often focus on stronger restrictions on the sale and purchase of firearms since gun-related injuries and deaths have been repeatedly correlated with firearm possession rates. Such proposals like the assault weapons ban of 2021<sup>1</sup> continue to be a major point of political controversy in the United States.<sup>2</sup> To inform the political debate and to design effective policy, access to accurate and spatially resolved firearm possession data is therefore of major importance. However, due to illegal sales and the lack of a nationwide registry for firearm ownership, such data are not easily obtained, and researchers have to rely on proxy variables to estimate firearm possession rates across different states. These proxy variables range from self-reported survey data to the number of federal background checks and the number of suicides or homicides committed with guns. As none of these proxy variables is believed to capture firearm possession rates sufficiently well by itself,<sup>3</sup> researchers often choose to combine several variables to arrive at more precise estimates of gun ownership.<sup>4</sup>

While many methods to produce such estimates are available in the scientific literature, most of them model firearm possession rates on a state-by-state basis without taking interactions between states into account. This assumption is, however, questionable. Regulations differ

between states, and hence, a significant number of buyers might decide to purchase firearms in neighboring states where access is less restricted. In addition, mobility of illegal firearms might not be captured sufficiently well when dynamic interactions between states are ignored.

In this issue of *Patterns*, in order to mitigate these limitations, Barak-Ventura, Ruiz Marín, and Porfiri<sup>5</sup> have developed a spatiotemporal model of firearm ownership across the United States that incorporates interstate relationships. By adapting the Spatial Durbin Model,<sup>6</sup> a tool borrowed from spatial econometrics, the researchers from New York University and the Universidad Politécnica de Cartagena combine the proxy variables “number of background checks per capita” and “fraction of suicides committed with firearms” with spatial interaction variables such as distance between states to provide new estimates of monthly state-level firearm possession rates. The model is then calibrated with the help of survey data on firearm possession and is found to perform better than a modeling approach where spatial interactions are ignored.

While having good estimates of firearm possession rates is valuable to policy makers by itself, public attention is often directed at causal questions like “Will a reduction in firearm ownership reduce the number of mass shootings? And if so, by what extent?” As firearm ownership and occurrence of mass shootings might both be influenced by a third variable (or several other variables), such questions cannot be answered by a simple correlation analysis. However,

throughout recent years, researchers have developed a variety of techniques to infer causal relationships from data, at least if certain assumptions are met. The most widespread approaches to causal inference in time series data are Granger causality<sup>7</sup> (especially in economics and other social sciences) and the causal calculus of Pearl.<sup>8,9</sup> The method of choice of Barak-Ventura, Ruiz Marín, and Porfiri is transfer entropy causation,<sup>10</sup> an approach derived from information theory that can be understood as a non-linear extension of the inherently linear Granger causality approach. In a nutshell, transfer entropy quantifies the amount of uncertainty that is reduced in future values of a variable Y by knowing the past of a second variable X in addition to the past values of Y.

In their causal analysis, the researchers discover that their estimated firearm ownership variable unveils significant causal links to the occurrence of mass shootings and media coverage on gun control. Most importantly, these links are no longer significant when replacing estimated firearm ownership with any of their proxy variables “background checks per capita” or “suicides committed with firearms.” Their result that, according to the transfer entropy interpretation of causality, estimated firearm ownership is causal for the occurrence of mass shootings will be a particularly interesting input for the public and political discourse on gun control laws in the United States.

#### DECLARATION OF INTERESTS

The author is also affiliated to the Institute of Data Science of the German Aerospace Center as a long-term guest scientist.



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