MERC PhD Project Proposal

Title of the research project

Causal relationships within the firearm ecosystem

Keywords

Criminology, Dynamical Systems, Human Behavior, Network Science, and Time-Series Analysis

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Project description

Firearm-related harms pose an imminent threat to America's prosperity and health. In 2017, firearm-related deaths surpassed those due to motor vehicles, amounting to 39,773 deaths (12.2 per 100,000 population), or approximately 109 per day. Now, firearm-related deaths account for 16.4% of all injury-related deaths in the U.S; among them, 96.5% are caused intentionally, including

homicide (36.5%) and suicide (60.0%). Just as these figures place the U.S. as the high-income country with the highest firearm homicide and suicide rates, they also define it as the country with the most frequent mass shootings.

There is surprisingly little quantitative research on the underlying causes of firearm-related harms, and existing research is far from conclusive. A recent systematic review and meta-analysis of over 9,000 articles and reports proposed that the majority of the studies on measures to reduce firearm-related harms through public policies suffers from key methodological limitations and addresses only a few of the many firearm-related harms (Rand Corporation, 2018). Before 2018, there was no comprehensive repository for data on violent deaths in the U.S., because many states did not opt to participate in the National Violent Death Reporting System. There is also disagreement and inconsistency over some basic definitions: for example, there is no formal definition of mass shooting. Based on these major deficits, the state of knowledge on the causes of firearm-related harms is limited and hotly debated.

The work of Prof. Porfiri and collaborators has been likely the very first mathematically-principled study into what we call the "firearm ecosystem" (Porfiri et al., 2019). This work, presented as part the MERC lectures by Prof. Porfiri, lays the foundations for an improved understanding of the role of the fear of regulations on firearm purchases, challenging one of the most well accepted explanation for increased firearm sales after a mass shooting. Through the application of the information-theoretic concept of transfer entropy, Prof. Porfiri demonstrated that media coverage on firearm regulation has a causal role on firearm sales, more so than media coverage on violence. Hence, people are more likely to purchase weapons as they fear their right to bear a firearm will be curtailed, rather than for their desire to self-protect – which was the classical theory till Prof. Porfiri's paper. The methodology underlying this effort was later extended through a combined spatio-temporal analysis by Profs. Porfiri and Ruiz (Porfiri, Barak-Ventura, and Ruiz, 2020) and some results on leader-follower relationships among states have been established by De Lellis and Porfiri (De Lellis and Porfiri, 2020).

While these efforts were very well received by the technical community and address key methodological questions on the firearm ecosystem, they are just the beginning of a long journey which we hope will bring along motivated students from MERC. Thus far, we have only focused on mass shooting, which make up only the 0.1% of casualties due to firearm violence. It is of the utmost importance to clarify causal relationships that explain any form of violence through objective and rigorous analysis. Identifying causes of firearm-related harms is the first step toward diagnosing, predicting, and controlling factors that affect public safety. While firearm prevalence is considered the most obvious cause, a conclusive assessment of this relationship is elusive. Most epidemiologic studies on the relationship between firearm prevalence and firearm-related harms employ correlation, linear regressions, or evidence-based inference, none of which can establish causality—especially if the true relationships are nonlinear.

The chief goals of this project are to decipher causal relationships between firearm prevalence, firearm-related harms, and media exposure at national and state levels, and to systematically explore the influence of other potential explanatory factors, such as social and economic conditions, on these causal links. Toward this goal, the student will pursue research along three fundamental directions:
i)   Expanding our existing database of background check as a proxy of firearm sales to include data on firearm homicide and suicide from the Center for Disease Control data inquiry

system, media coverage from ProQuest database, and media pressure through social media through Twitter data.

ii)   Improving on the theoretical framework to investigate causal relationships with respect to firearm homicide, mass shootings, and suicide within a network representation of the entire country.

iii) Assessing the role of socioeconomic conditions, including unemployment, poverty, educational attainment, migration, housing vacancy, and home ownership. To reduce the complexity of the phase space and allow for an information-theoretic analysis, we might aggregate these data through dimensionality reduction methods.

Relevance to the MERC PhD Program

Developing quantitative methods to identify the drivers of human actions is a true challenge for the scientific community, and its potential contribution towards informed policy making is invaluable. Achieving this goal requires a truly interdisciplinary effort that merges network science, information theory, and data analysis. Therefore, this projects ideally fits the spirit of the MERC PhD program, with respect to its criteria of excellence, interdisciplinary nature, and transformative potential.

Methodologically, this project will represent a unique opportunity to enhance the skills of MERC students in statistical non-parametric modeling and to learn methods for causation inference from data. The student will be guided by three supervisors from US, Italy, and Spain, and they will have the opportunity to learn mathematical and statistical tools that are at the frontier of knowledge. Furthermore, they will learn how to better discriminate between the concepts of causation and association. Along with theory, the students will be trained in data collection, spanning rigorous exploration of official sources and internet scraping from social media. By working on a concrete dataset, the students will have the opportunity to appreciate how the concepts and the scientific approach learned at the MERC PhD school translate to the solution of real-world complex problems.

Key references

-De Lellis, P., and Porfiri, M. (2021), Detection of influential nodes in network dynamical systems from time-series, IEEE Transactions on Control of Network Systems, doi.org//10.1109/TCNS.2021.3061953.
-Porfiri, M., Barak Ventura, R., Ruiz Marin, M. (2020). Self-protection versus fear of stricter firearm regulations: examining the drivers of firearm acquisitions in the aftermath of a mass shooting. Patterns 1(6), 100082.
-Porfiri, M., Sattanapalle, R.R., Nakayama, S., Macinko, J., and Sipahi, R. (2019). Media coverage and firearm acquisition in the aftermath of a mass shooting. Nature Human Behaviour 3, 913-921.
-Rand Corporation, (2018). The science of gun policy: a critical synthesis of research evidence on the effects of gun policies in the United States," Santa Monica, California.

Joint supervision arrangements

The supervisors are close friends who are excited about the project and discuss science on a regular basis, multiple times per week. As such, students will be part of a vibrant team, where discussions continuously happen in an organic and natural manner. Hence, the frequency of meetings will depend on the stage of the research carried out by the student and on the very need they will have. We expect that there will be periods when meeting twice per month with the all group will be sufficient, for instance, when the student is learning and studying some methodology or the state of the art, and other periods when one-on-one meetings with any of the supervisors should happen

two or three times per week, for example, when dealing with the development of new methods to infer causality from data.

Location and length of the study period abroad (min 12 months)

The New York University (NYU) Tandon School of Engineering is the engineering and applied sciences school of NYU. Tandon is the second oldest private engineering and technology school in the United States. Located in the Brooklyn Tech Triangle, ten minutes walking to the Brooklyn Bridge and connected with subway or NYU to any of the other NYU schools in the City. Prof. Porfiri is an Institute Professor (the highest distinction at NYU Tandon), with tenured appointments in Biomedical Engineering and Mechanical and Aerospace Engineering. Prof. Porfiri's laboratory, the Dynamical Systems Laboratory (DSL), was founded fifteen years ago with the vision of creating an interdisciplinary space with fundamental research in dynamical systems with clear societal impact. The laboratory is housed between the Center for Urban Science and Progress (CUSP) and the Department of Mechanical Engineering. MERC students joining the project will have office space in the newly renovated CUSP building and access to any of the DSL facilities. At the DSL, they will be fully integrated in any of the lab activities, such as seminars, workshops, focused courses for professional developments, and collaborative efforts within and outside the group.

Technical University of Cartagena (UPCT) offers several different study programs across engineering, economics, and business sciences. The historical city of Cartagena belongs to the autonomous province of Murcia. Cartagena is located in the southeast of Spain, right at the Mediterranean Sea. The combination of tradition and modernity gives UPCT a vibrant, adventurous and innovative character. Prof. Ruiz is the principal investigator of the excellence research group Economic Modelling and Non-Parametric Statistic (EMODs), an interdisciplinary research group specialized in the analysis and applications of nonlinear time series, complex networks and spatial processes. MERC students joining the project will have office space and access to any of the UPCT facilities.

Ideally, we would like the student to spend 18 to 24 months abroad to ensure ample opportunities for training and full integration with the supervisors' research teams. How to split the time between US and Spain will be discussed based on student preferences; we also anticipate that, under normal circumstances, Prof. Porfiri visits the Technical University of Cartagena regularly and so does Prof. Ruiz visits NYU.

Any other useful information

CUSP is a Tandon research center dedicated to the application of science, technology, engineering, and mathematics in the service of urban communities across the globe. CUSP was founded in 2012 as a partnership between NYU and NYC, motivated by a rapid trend of urbanization that will see 68% of the world's population live in cities by 2050. Using NYC as a living laboratory, CUSP contributes foundational knowledge and novel technologies for increasing our understanding of urban processes and solving complex urban problems, from ensuring the health and wellness of urban populations, to making our cities more accessible and inclusive, to supporting local governments to be more responsive to citizens' needs. CUSP members include faculty and researchers from computer and data science; civil, electrical, biomedical, and mechanical engineering; human-technology design and interaction; applied mathematics and statistics; public health and policy; and the social sciences. CUSP has a large number of ongoing partnerships with city agencies, non-profits, industry, academic organizations, and start-ups that will provide project-

based internship opportunities for trainees. These convergent research activities and synergistic connections with NYC put CUSP at the forefront of fundamental and applied research in urban accessibility, a priority of NYC's administration.

Prof. Porfiri is the inaugural director of the CUSP Interdisciplinary Doctoral Concentration, which, like MERC, offers a collaborative environment for excellence in interdisciplinary research. MERC students will integrated in doctoral activities at CUSP, thereby promoting collaborations with other junior researchers. As an example of potential synergies, Prof. Porfiri is the lead, principal investigator of the National Science Foundation Project *LEAP-HI: Understanding and Engineering the Ecosystem of Firearms: Prevalence, Safety, and Firearm-Related Harms*, in cooperation with the interdisciplinary research groups of the University of California, Los Angeles, Northeastern University, and Georgia State University, whose scope is strictly related to this MERC research project. The MERC student will be welcome to be involved in the activities of the project, participate in related meetings, thus further expanding their learning opportunities.