

Innovation and Interdependence: Evidence from Gene-Editing Technology

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Technological breakthroughs carry great promise but often escalate economic competition and heighten public anxiety, creating new challenges for governments. We argue that breakthroughs trigger two distinct mechanisms that reshape regulatory politics: (1) accelerated incentives for regulatory arbitrage and (2) the potential for controversies to spark international public backlash. First, technological advancement generates forum-shopping behavior as private actors race to develop the new technology. Researchers and firms may seek to evade national rules by relocating to more permissive jurisdictions. Second, public unease about new technologies creates the potential for backlash in the wake of controversial applications. This backlash can spill across borders: accidents or misuse in one jurisdiction undermine support for research and commercial development elsewhere. Together, these processes link the regulatory fate of states, undermining their ability to regulate in isolation. We test and find evidence for these mechanisms in the domain of gene editing, a field that has been transformed by the introduction of CRISPR technology in 2012. Our theory and findings shed new light on the regulatory politics of breakthrough technologies.

Los avances tecnológicos suelen ser muy prometedores, pero, con frecuencia, contribuyen a intensificar la competencia económica y a aumentar la ansiedad pública, lo que crea nuevos desafíos para los Gobiernos. Argumentamos que los avances tecnológicos desencadenan dos mecanismos distintos que remodelan la política regulatoria: Por un lado, suponen incentivos acelerados para el arbitraje regulatorio y, por otro lado, tienen el potencial de crear controversias para provocar una reacción pública internacional. En primer lugar, el avance tecnológico genera un comportamiento en materia de búsqueda del foro más favorable a medida que los actores privados compiten por desarrollar la nueva tecnología. Los investigadores y las empresas pueden tratar de evadir las normas nacionales trasladándose a jurisdicciones más permisivas. En segundo lugar, el malestar público por las nuevas tecnologías genera la posibilidad de que se produzca una reacción en contra a raíz de aplicaciones controvertidas. Esta reacción en contra puede extenderse más allá de las fronteras: los accidentes o el uso indebido en una jurisdicción disminuyen el apoyo a la investigación y el desarrollo comercial en otros lugares. En conjunto, estos procesos vinculan el destino regulatorio de los Estados, reduciendo su capacidad para regular de forma aislada. Ponemos a prueba y encontramos evidencia de estos mecanismos en el dominio de la edición de genes, un campo que se ha transformado con la introducción de la tecnología CRISPR en 2012. Nuestra teoría y nuestras conclusiones arrojan nueva luz sobre la política regulatoria de las tecnologías innovadoras.

Chargées de maintes promesses, les avancées technologiques engendrent souvent une escalade de la concurrence économique et un renforcement des craintes de la population. Aussi apparaissent de nouveaux défis pour le gouvernement. Nous affirmons que les avancées déclenchent deux mécanismes distincts qui remodelent la politique réglementaire : 1) une accélération des incitations à l'arbitrage réglementaire et 2) un potentiel déclenchement d'un retour de bâton public à l'international par les polémiques. D'abord, l'avancement technologique génère un comportement de "forum shopping", les acteurs privés se pressant de développer la nouvelle technologie. Les chercheurs et entreprises peuvent chercher à se soustraire aux règles nationales en déménageant dans une juridiction plus permissive. Ensuite, l'inquiétude de la population quant aux nouvelles technologies crée une possibilité de retour de bâton à la suite d'applications controversées. Ce retour de bâton peut se répandre au-delà des frontières : les accidents ou détournements au sein d'une juridiction nuisent au soutien à la recherche et au développement commercial dans d'autres. Ensemble, ces processus lient le destin réglementaire des États, et donc compliquent leur capacité à créer des réglementations de façon isolée. Nous testons et trouvons des éléments prouvant l'existence de ces mécanismes dans le domaine de l'édition génomique, qui s'est vu transformé par l'introduction de la technologie CRISPR en 2012. Notre théorie et nos conclusions apportent un nouvel éclairage sur la politique de réglementation des technologies révolutionnaires.

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Introduction

Technological breakthroughs are a defining feature of contemporary life. Advances in fields like biotechnology, digital finance, and artificial intelligence promise improved welfare through enhanced health, productivity, and economic growth. They also pose significant risks if applied in ways that cause social harm or violate ethical norms. The recent revolution in gene-editing technology, for example, has been celebrated for facilitating new medical therapies and also criticized for enabling controversial modifications of human DNA.

Governments confront a variety of economic and political pressures as they consider regulating technologies. Classic accounts of regulatory politics cite factors like interest group influence (Yackee 2006; Mattli and Woods 2009; Drutman 2015; Perlman 2023), variation in political institutions (Majone 1991; Milner 2020), the desire to insulate labor markets from disruption (Ruggie 1982; Thewissen and Rueda 2019), and pressures arising from globalization (Mosley 2000; Brutger and Pond forthcoming 2025). While these forces are undoubtedly important, we argue that technological breakthroughs—sudden, disruptive innovations that dramatically transform or replace existing practices—feature at least two distinguishing characteristics that alter the regulatory landscape for states.

The first is a particularly intense competition to develop and commercialize the new technology. Technological breakthroughs create new market opportunities (Shea 1998) and pave the way for subsequent advancements (Doraszelski 2004). Researchers and firms that outrace their peers can secure significant returns in profit and status. This race also carries geopolitical stakes, as states compete to become industry leaders. The second distinguishing feature is public anxiety about the new technology. Breakthrough technologies create novel capabilities, have an uncertain trajectory of future development, and often entail substantial risks—all of which generate apprehension among citizens and consumers (Zhang and Dafoe 2019). The result is a fragility in public support for new applications of the technology.

In this paper, we explore how these contextual features shape the regulatory politics of breakthrough technologies. We identify two processes that constrain national governments as they craft rules about the use and application of the technology. These processes are likely to be present in other regulatory contexts, but we argue they are heightened in the aftermath of technological breakthroughs.

First, we argue that the intensified race to develop breakthrough technologies increases incentives for private actors to forum shop across states. Cross-national differences in regulations create opportunities for regulatory arbitrage, whereby scientific and commercial development relocates to jurisdictions with more permissive regulatory environments. As international competition intensifies, governments may face pressure to weaken standards to lure researchers, firms, and capital from elsewhere. While existing work has found mixed support for regulatory arbitrage and competition in other domains (Genschel and Plumper 1997; Mosley 2000), we argue that technological breakthroughs often exacerbate the process by increasing the perceived returns of relocation.

The second process is rooted in fragile public attitudes regarding technological breakthroughs. Public anxiety makes new technologies highly vulnerable to controversies that expose ethical or safety concerns. These controversies of-

ten spur intense public backlash, undermining support for subsequent research and commercial development. An effective regulatory regime could guard against this backlash by enforcing standards to limit controversial applications. However, we argue that public backlash is rarely limited to the regulatory jurisdiction in which a controversy emerges. Instead, backlash tends to spill across national boundaries, such that controversies in one state affect public attitudes in another. As a result, one government's decision to weaken regulation can damage confidence in the technology around the world. We are not aware of existing scholarship that examines the transmission of public backlash across regulatory jurisdictions. Nonetheless, we argue that it is an important challenge in the governance of breakthrough technologies.

Notably, both of these processes represent challenges that emerge due to interdependence between states. As governments consider how to regulate breakthrough technologies, they must grapple with the possibility that restrictive rules will create an exodus of capital and talent that put the country at a competitive disadvantage. They are also constrained by the use of the technology in other states: the potential for international public backlash also means that effective national governance cannot insulate a country from poor regulation abroad. Both dynamics limit the policy autonomy of states, complicating efforts to govern novel technologies.

We examine these processes in the case of gene editing, a field in the midst of a technological revolution. Gene editing refers to the targeted manipulation of an organism's genetic material. The emergence of clustered regularly interspaced short palindromic repeats (CRISPR) and associated techniques in the last decade provides a dramatically more accurate and economical method for editing genes. In recognition of the technology's revolutionary capacity for "rewriting the code of life," CRISPR architects Emmanuelle Charpentier and Jennifer Doudna received the Nobel Prize in Chemistry in 2020. The introduction of CRISPR greatly expanded the development and application of gene-editing technology while also triggering concerns about unethical or harmful misuse. We argue that these conditions facilitate the two processes described above.

We probe the theoretical mechanisms with two sets of empirical tests. We first analyze a novel dataset on gene scientist employment to examine patterns of regulatory arbitrage. This test seeks to answer the research question: How do technological breakthroughs interact with national regulations to shape the cross-border movement of gene-editing researchers? We leverage the 2012 introduction of CRISPR as a temporal shock to examine whether researchers are more likely to seek out permissive regulatory jurisdictions. Our results are consistent with theoretical expectations: we observe a pronounced acceleration of relocation to countries with weaker gene-editing regulations after 2012.

In a second test, we assess how controversies involving breakthrough technologies affect public opinion at home and abroad. To test for international public backlash, we implement a survey experiment in which American respondents react to a hypothetical controversy involving the birth of genetically altered infants, varying the country in which the controversial gene-editing activity occurred. We find that both foreign and domestic gene-editing controversies negatively affect domestic public support for gene-editing research.

Our paper adds to a growing literature on international competition, cooperation, and technological change

(Drezner 2019; Milner and Solstad 2020; Perlman 2020; Jia et al. 2022). We advance novel arguments about the regulatory politics of breakthrough technologies and offer new evidence in a domain, biotechnology, that has been largely neglected in international relations and political science.¹ Biotechnology, in particular, is likely to increase in salience as governments and citizens grapple with the unprecedented technological progress in this domain. Our paper is an important initial step in examining this field.

More broadly, we identify two theoretical mechanisms—regulatory arbitrage and international public backlash—that link countries' fates as they govern breakthrough technologies. In doing so, we demonstrate how technological shocks interact with patterns of economic and political exchange to constrain governments' ability to craft policy (Mansfield and Rudra 2021). Among other things, these mechanisms have implications for the emergence and design of global governance institutions (Koremenos, Lipson, and Snidal 2001), which may be charged with managing these spillovers.

Technology and International Politics

International relations research has identified a range of political outcomes associated with technological advancement.² Researchers have long been interested in the effects of technology on interstate bargaining and conflict. Military technology affects the severity of the security dilemma and the stability of interstate cooperation (Jervis 1978). Medical innovations such as vaccines and field medicine alter battlefield tactics and combat effectiveness (Fazal 2014). More broadly, technological innovation and adoption shape the economic and military power of states (Drezner 2019). This provides strong incentives for governments to invest in technology, especially when they confront external threats (Taylor 2012) and when the international system is more competitive (Milner and Solstad 2020).

In addition to shaping state behavior, technological innovation has allowed citizens, firms, and political groups to forge new transnational links. Communications technology facilitates cooperation among advocacy groups (Hall, Schmitz, and Dedmon 2020; Keck and Sikkink 1999) as well as transnational extremist movements (Gohdes 2018; Mitts 2021). Improvements in transportation, financial, and digital technologies lower the costs of transnational exchange, spurring waves of globalization and deepening economic interdependence (Rogowski 1987; O'Rourke and Williamson 2001). These advancements increase cross-border flows of information, money, and goods, generating new opportunities for coercion and cooperation among states (Keohane and Nye Jr 1973; Farrell and Newman 2019).

These new patterns of international and transnational exchange create regulatory challenges for governments. For example, governments face conflicting incentives regarding the desired pace of technological adoption and continued innovation. They frequently want to limit the social and economic disruptions associated with new technologies, but a restrictive regulatory posture risks putting the country at a competitive disadvantage (Milner and Solstad 2020; Taihagh, Ramesh, and Howlett 2021). More broadly, governments grapple with the increasing cross-border mobility of information and economic assets that often accompany

technological innovation. This enhanced mobility and the associated threat of exit can constrain governments' ability to craft domestic policy in many domains (Genschel and Schwarz 2011; Mansfield and Rudra 2021).

We build on this body of work, examining how technology and the transnational flows it facilitates pose regulatory challenges for states. While existing research has largely focused on long-term technological shifts, we examine the political effects of *technological breakthroughs*—sudden, disruptive innovations that dramatically transform or replace existing processes. Technological breakthroughs are distinct from incremental improvements in that they contain a high degree of new knowledge (Dewar and Dutton 1986), establish a foundation for future advancements, and accelerate further innovation (Doraszelski 2004). These breakthroughs often trigger a phase of intense competition to improve, apply, or adapt the relevant technology (Hill and Rothaermel 2003).

Examples of technological breakthroughs include the discovery of nuclear fission, the invention of the integrated circuit, and the recent development of generative artificial intelligence tools. Each of these technologies represents a large and sudden advancement over existing methods, spurring new opportunities and concerns about potential applications. We argue that breakthroughs merit distinct scholarly attention for two reasons. First, they create an environment of excitement, uncertainty, and anxiety that poses unique regulatory challenges for states. They are distinguished in particular by private actors' eagerness to race ahead and public unease over the risks of harm. Second, the choices made by scientists, firms, and regulators in the aftermath of breakthroughs often serve as critical junctures (Collier and Collier 2002) that guide the technology's future trajectory. This underscores the importance of understanding the incentives these actors face as they navigate this environment.

Regulating Technological Breakthroughs

We argue that technological breakthroughs pose a set of unique regulatory challenges for governments. Two key processes arise in the wake of breakthroughs: (1) enhanced incentives for regulatory arbitrage and (2) the potential for controversies to spark international public backlash. Breakthroughs trigger these processes by pushing technology to a new and uncertain frontier—inciting both a race for further development and substantial public anxiety. While the two dynamics are distinct, they both tend to reduce the policy autonomy of national governments as they formulate a regulatory response to new technologies.

The two processes we identify are far from exhaustive, and different policy domains are likely to have unique features that shape the incentives and policy autonomy of regulators.³ Our study is an important initial step in characterizing the distinct economic and political environment of technological breakthroughs. A key implication of our argument is that breakthroughs link the regulatory fate of states, constraining their ability to govern technology in isolation. We develop the logic of each process below.

¹For exceptions, see Oye and Wellhausen (2009) and Perlman (2020).

²Following the conventional definition in economics, we conceptualize technological advancement as a new process or method that increases productivity, enabling actors to produce more output with fewer inputs.

³For example, some breakthroughs create or exacerbate global public goods problems that confound national policy responses (e.g., the invention of the international combustion engine has exacerbated the problem of climate change).

Regulatory Arbitrage

Our first mechanism focuses on how technological breakthroughs redistribute patterns of research and production across borders. Breakthroughs set off a race to develop and commercialize new applications of the technology (Cubero, Gbadegeshin, and Consolación 2021). If national rules put constraints on the technology, researchers and firms have incentives to relocate to more permissive jurisdictions. This process of regulatory arbitrage means that technological development shifts toward countries with less onerous regulation, potentially increasing the risk of accidents, misuse, or controversial applications.

Three assumptions underpin the argument that technological breakthroughs accelerate regulatory arbitrage. First, the breakthrough must increase the perceived economic or status returns of adopting and further developing the technology. This assumption holds when technological advancement creates new economic opportunities by lowering production costs and allowing novel markets to emerge (Shea 1998). After a breakthrough is introduced, researchers, entrepreneurs, and firms race to develop applications to exploit these opportunities. The stakes of this competition are significant. The estimated global market for artificial intelligence, for example, was \$184 billion in 2024 and will exceed \$826 billion by 2030.⁴ The quantum computing and advanced robotics industries are similarly expected to grow drastically over the next decade.⁵ Pioneer firms often secure a first-mover advantage that endures even as competitors subsequently enter the market (Lieberman and Montgomery 1988; Agarwal and Gort 2001), providing substantial motivation for technological development.

Second, there must be inconsistencies in national regulation such that some jurisdictions are more favorable to rapid technological development. Countries that prohibit or limit applications of the technology should be less attractive environments for private actors who wish to push the frontier forward.⁶ The magnitude of regulatory divergence among countries is likely to differ across issue areas. In the domain of gene editing, inconsistent rules stem from different cultural and religious norms, historical experiences, and state capacity (see "Regulation of Gene-Editing Technology" section). Early-stage governance of artificial intelligence differs between the United States and Europe in terms of the pace, scope, and depth of regulation (Cha 2024). In general, national regulatory action tends to lag behind technological breakthroughs. This can increase inconsistency in the global regulatory landscape since the use of novel technologies is often governed by a diverse set of legacy rules originally crafted for other issues.

Third, private actors such as researchers and firms must have sufficient freedom of movement to relocate to more permissive jurisdictions. Their ability to do so is shaped by the physical, legal, and political constraints that shape cross-border mobility. Some technologies require significant physical capital which makes relocation difficult. In other cases—often when technologies have direct military applications—states strategically limit the mobility of technological ex-

pertise or material inputs.⁷ More routinely, scientists are able to collaborate with colleagues abroad and seek employment in other jurisdictions if they wish. Firms similarly may have latitude to shift activities overseas. Generally, we expect technological breakthroughs to accelerate arbitrage behavior when actors have the ability to relocate across national borders. If constraints on movement are prohibitive, states can adopt restrictive regulatory postures without increasing forum-shopping behavior (Mosley 2000).

When these three conditions are met, technological breakthroughs tend to relocate research and development to less restrictive regulatory environments—a hypothesis we test below. These incentives can set the stage for regulatory competition among governments as permissive jurisdictions lure investment and human capital from more restrictive countries.⁸ An implication of this process is that breakthrough technologies may receive less oversight than in a counterfactual world with fewer arbitrage opportunities.

Public Backlash from Controversies

A second challenge in regulating technological breakthroughs is based on public attitudes toward new technologies. Public opinion is an important input to the trajectory of new technologies. Most directly, public attitudes influence regulation, which sets the pace and direction of technological development (Baron and Herzog 2020). Beliefs about the safety and morality of new technologies also shape consumer demand for associated products (Zhang and Dafoe 2019), which is a key driver of commercial development.

We argue that public attitudes about new technologies are often fragile. Technological breakthroughs challenge existing systems of practice and introduce uncertainty about the safety and ethical implications of the new technology. Most technologies are susceptible to misuse, unethical applications, or harmful accidents. With no pre-existing reference frame to anchor individuals' views, high-profile events can create rapid shifts in public opinion. For example, the infamous nuclear accidents at Chernobyl and Three Mile Island impacted global public support for nuclear energy decades after the events (Verplanken 1989; Lindell and Perry 1990; Nohrstedt 2005).

Public anxiety and uncertainty are highest in the period following technological breakthroughs when the path of future technological development is unclear. This period is particularly vulnerable to public backlash when controversies arise. Revelations of unanticipated effects or scandalous applications of the new technology can quickly turn public opinion against it, leading to reductions in public funding and knee-jerk regulatory responses that constrain even responsible scientific activity.

The recent history of gene therapy provides an example of such backlash. In 1999, 18-year-old Jesse Gelsinger joined a clinical trial at the University of Pennsylvania for a gene therapy treatment. Unlike the other trial participants, Gelsinger suffered an unexpected and ultimately fatal immune response. The tragic death led to an immediate and precipitous drop in public support and consumer demand for gene therapies. As gene-editing pioneer Jennifer

⁴"Market Insights: Artificial Intelligence—Worldwide." Accessed June 20, 2024. <https://www.statista.com/outlook/tmo/artificial-intelligence/worldwide>.

⁵"Quantum Computing Market to Grow Exponentially; Increasing Product Applications to Generate Remunerative Market Opportunities: Fortune Business Insights." *Global News Wire*, March 4, 2022.

⁶We focus on cases where governments choose to prohibit or allow technological research and development. The broader question of whether regulation in general impedes or enhances innovation is disputed (Blind 2016; Aghion, Bergeaud, and Van Reenen 2023).

⁷For example, after World War II the United States placed visa restrictions and travel controls on scientists with nuclear weapons expertise.

⁸Scholars have found evidence for regulatory arbitrage and competition in tax policy, financial regulation, and environmental standards (Trachtman 1993; Angelini and Cetorelli 2003; Konisky 2007; Genschel and Schwarz 2011), though countervailing pressures can sometimes generate a "race to the top" (Porter 1996; Genschel and Plumper 1997; Prakash and Potoski 2006).

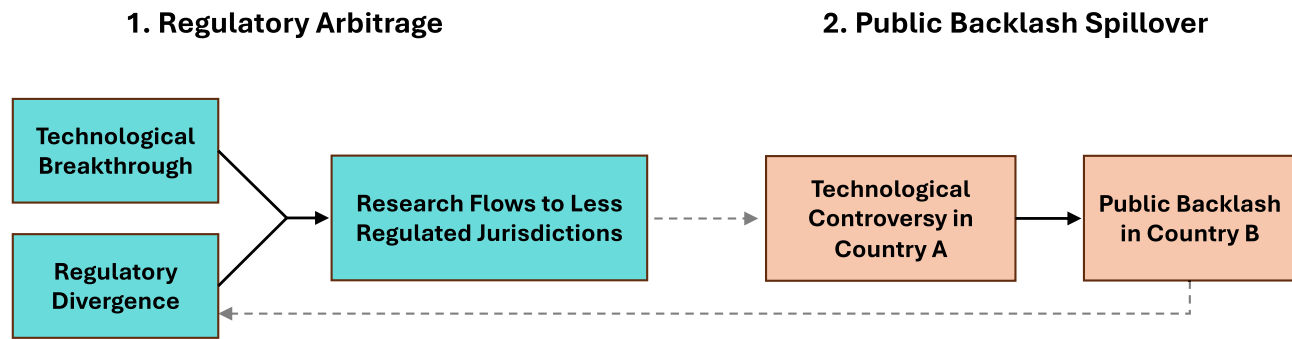


Figure 1. Illustration of the theoretical mechanisms and their interaction.

Doudna recalls, the incident “made the whole field of gene therapy go away, mostly, for at least a decade. Even the term gene therapy became kind of a black label” (Rinde 2019).

This example illustrates how an uncertain environment with few consistent cues engenders instability in public attitudes. As a result, novel technologies that rely on public support often develop in fits and starts, with periods of promising technological advancements interrupted by crises of public confidence. The related field of genetically modified organisms experienced a similar dynamic, where media exposure to controversies has soured public opinion (Prakash and Kollman 2003; Vigani, Raimondi, and Olper 2012). Ciocca, Horowitz, and Kahn (2021) similarly note the potential for “hype-induced backsliding” in the field of artificial intelligence.

Notably, public backlash is not limited to the regulatory jurisdiction in which the controversy occurs. Citizens may respond to accidents or misuse abroad by reducing their support for the technology at home. We argue backlash is therefore usefully conceptualized as a negative spillover that spans national borders. In practice, this means that governments cannot safeguard public confidence simply by maintaining an effective regulatory regime. Controversies abroad may damage support for new technologies even in jurisdictions that are comparatively well-regulated. While regulatory arbitrage has been documented in other contexts, we are not aware of existing scholarship that examines the potential for international spillovers in public backlash. Nonetheless, we expect that it is an important regulatory challenge that emerges whenever a technological breakthrough is associated with safety risks or ethical concerns.

Potential Interactions between the Two Mechanisms

Figure 1 visualizes the two theoretical processes outlined above. The arbitrage mechanism, depicted on the left, is activated when a technological breakthrough occurs and countries diverge in how they regulate its application and development. This triggers forum shopping as research activity relocates to weakly regulated jurisdictions. On the right, the public backlash mechanism is activated when a controversy emerges over the use of the technology in a given country. We anticipate this will decrease public support for the technology in both the home jurisdiction as well as in other countries. The solid arrows in the figure indicate hypothesized causal relationships in each process which we formally test in the empirical section below.

While each mechanism can occur in isolation, they may also interact in a dynamic process of regulation, technological development, and response to controversies. We spec-

ulate that there are two principal sources of interaction, which we represented by dashed arrows in figure 1. First, the regulatory arbitrage mechanism may increase the overall likelihood of technological controversies. Strategic forum shopping by scientists and firms means that more technological development occurs in permissive regulatory environments. If these environments allow actors to “push the envelope” in ways that incite scandals, we should expect more frequent technological controversies as a result.⁹ We note that even if states anticipate this undesired outcome, they have incentives to maintain relatively weak regulations: doing so allows them to capture the benefits of a permissive regulatory posture (the attraction of profit and scientific capital) while spreading the costs across other parties (the risk of an international backlash that spills across borders).¹⁰

A second interaction could occur if the backlash created by technological controversies triggers a regulatory response in both the home country and other jurisdictions. Once controversies happen, they may effectively reduce regulatory divergence by prompting all countries to impose more onerous regulatory constraints in response to public concern. An implication is that the two mechanisms could jointly contribute to regulatory *convergence* across countries. While such an outcome is beyond the scope of the present study, we acknowledge the possibility that the processes we examine here may represent short-term dynamics that contribute to a longer-term equilibrium of policy convergence.

South Korea’s experience in the biotechnology industry at the turn of the twenty-first century provides a useful illustration of the mechanisms we seek to examine. Spurred by its robust scientific infrastructure and permissive regulatory environment, South Korea became a leader in cloning technology in the late 1990s. High-profile experiments in cloning, including the successful cloning of animals and reports of clones of human embryos, aroused public anxiety and led the government to explicitly ban human cloning in 2002.¹¹ However, cloning research on embryonic stem cells continued to be funded and lauded by the government. In late 2005, reports surfaced that the country’s most celebrated cloning researcher had fabricated findings and coerced female lab members to donate eggs for his re-

⁹Of course, controversies are not limited to less-regulation jurisdictions: actors in strictly regulated states may initiate scandals that depress global public confidence in the technology.

¹⁰This undesired outcome could be resolved if states upheld a common regulatory standard—one reason why many call for an internationally coordinated policy response to technology governance.

¹¹Claims by the South Korean company Clonaid that it successfully cloned a human baby turned out to be a hoax, though it still played a pivotal role in encouraging the government to strengthen regulations.

search. The ensuing scandal soured public support for related technologies in Korea and abroad. The Korean government strengthened regulations and increased scrutiny of cloning research (Hong 2008). In addition to illustrating public opinion dynamics, the episode offers some support for regulatory arbitrage dynamics. Domestic scientists immediately objected to the new regulations, arguing “that only the Republic of Korea was regressing at a time when foreign scientists [had] started research on somatic ... cells” (Hyeon et al. 2023, 6). In the ensuing years, Korean scientists moved their labs to the United States, China, Qatar, and other less-regulated countries in order to continue research (Zastrow 2017).¹² We provide an expanded discussion of the Korea example in Online Appendix A.6. The following section turns to the field of gene editing, the basis for our empirical tests.

Gene Editing: Technological and Political Landscape

We look for evidence of our two mechanisms in the domain of gene editing, a field that has been transformed by scientific advances over the past decade. The purpose of gene editing is to suppress or alter the biological traits of an organism. The field emerged in the 1970s when scientists began splicing together naturally occurring genetic material, and by the early 2000s scientists were leveraging cells’ own DNA-repair technology to selectively edit specific genes (Gupta et al. 2014).

The emergence of the CRISPR method in 2012 represents a particularly significant breakthrough in gene-editing technology. The name CRISPR refers to a series of repeating DNA sequences originally found in bacteria. These sequences allowed bacteria to recognize and destroy the DNA of harmful viruses. Scientists repurposed this technique for programmable gene editing (Jinek et al. 2012). The result was a significantly more accurate, efficient, and economical tool for altering DNA.

In the years since its development, CRISPR has become the dominant gene-editing technology (Carroll 2018).¹³ Like other breakthrough technologies, CRISPR dramatically reduced the costs associated with editing genes: By 2019, a gene-editing template that cost \$1000 to design using rival technologies could be produced with CRISPR for \$65 (Shwartz 2019). CRISPR’s low cost and ease of use have contributed to its rapid diffusion to laboratories around the world.¹⁴

The CRISPR technological breakthrough has stimulated a “biotechnological revolution” in basic research, clinical care, agriculture, and other fields (Knott and Doudna 2018). New gene therapies are being developed to treat cancer and correct harmful genetic mutations (Khan et al. 2016). Agricultural producers are applying CRISPR to both plants and livestock. Research teams have successfully altered the DNA of mosquitos to prevent the transmission of malaria (Gantz et al. 2015). More recently, gene-editing

¹²In the words of Hyeon et al. (2023, 9): “The Republic of Korea’s Bioethics Act was enacted in a way that allowed too much research. As a result, life science researchers have deviated and the level of regulation of the Bioethics Act has increased, hindering research development.”

¹³Figure A1 in Online Appendix shows the frequency of CRISPR patent applications compared to rival methods like transcription activator-like effector nucleases (TALENs).

¹⁴In Online Appendix Figure A2, we display the number of laboratories registered with AddGene, a popular genetic material repository for peer-reviewed genetics research. An employee of this repository estimated that 25% of requests are for CRISPR-related materials (Interview by authors, November 25, 2019). American laboratories are the largest group, followed by China, France, Japan, India, and Germany.

technology has been used to develop diagnostic tests and treatments for COVID-19 (Straiton 2020).

Regulation of Gene-Editing Technology

The use of gene-editing technology is governed by a fragmented patchwork of norms, national laws, and international guidelines. When targeted gene editing first became feasible in the 1970s, scientists attempted to construct self-governing arrangements for gene-editing research. In 1973, leading geneticists announced a voluntary moratorium on gene-editing experiments involving certain viruses and toxins (Berg et al. 1974). The moratorium was maintained for 2 years until it was replaced by formal guidelines adopted by the National Institutes of Health. Scientists involved in drafting the original guidelines argue that this decentralized approach was successful in constraining potentially inappropriate applications (Berg and Mertz 2010).

In recent years, similar efforts have sought to establish new norms for the research community. A 2019 conference of geneticists called for a global 5-year ban on editing DNA in human eggs, sperm, or embryos that are brought to term (Lander et al. 2019); however, there is dissent about this approach even among the most prominent gene researchers (Cohen 2019). The lack of consensus creates uncertainty about appropriate applications of gene-editing technology, potentially contributing to misuse. In addition, it is unclear whether voluntary, decentralized rules can succeed in an era when gene-editing technology is more accessible and diffusely distributed than in the 1970s.

As gene-editing technology progressed, national regulations began to supplement scientific norms. Early US guidelines built upon the partial gene-editing moratorium of 1973–4 (Baskin et al. 2016). Other countries followed suit as the technology became more widespread. Currently, there is significant variation in the structure and rigor of national rules. Some countries, for example, maintain a legal ban on the alteration of human germline cells.¹⁵ Some have less formal “guidelines” prohibiting germline editing, while others are more permissive in the constraints they place on the technology (Araki and Ishii 2014; Ishii 2017). Figure 2 displays a composite measure of national gene-editing regulations combining information from three recent surveys of regulatory policies.¹⁶ Countries are shaded according to regulatory rigor, with darker shades indicating more restrictive national rules.¹⁷

Inconsistent rules across countries stem, in part, from different historical experiences and cultural expectations regarding the appropriate use of gene-editing technology. For example, Germany’s experience with unethical experiments during the Nazi regime has shaped the state’s regulation of human subjects research. South Korea’s strict biological research guidelines arose in response to high-profile research ethics controversies (Resnik, Shamoo, and Krimsky 2006). The United States maintains comparatively weaker regulations for gene editing, consistent with a policy process that is more receptive to industry influence.¹⁸ Permissive regulations in China are driven in part by pressure to outpace Western countries in technological innovation (Kleiderman

¹⁵According to Ishii (2017), this group includes Canada, Brazil, Australia, and much of Western Europe.

¹⁶Source data are from Araki and Ishii (2014), Isasi, Kleiderman, and Knoppers (2016), and Baylis et al. (2020). For details on these measures and the construction of the composite measure, see “Regulatory Arbitrage” section.

¹⁷Countries with no identifiable gene-editing regulations are not colored.

¹⁸One biotechnology expert referred to US regulation of gene-editing technology as “the Wild West” (Interview by authors, September 21, 2020).

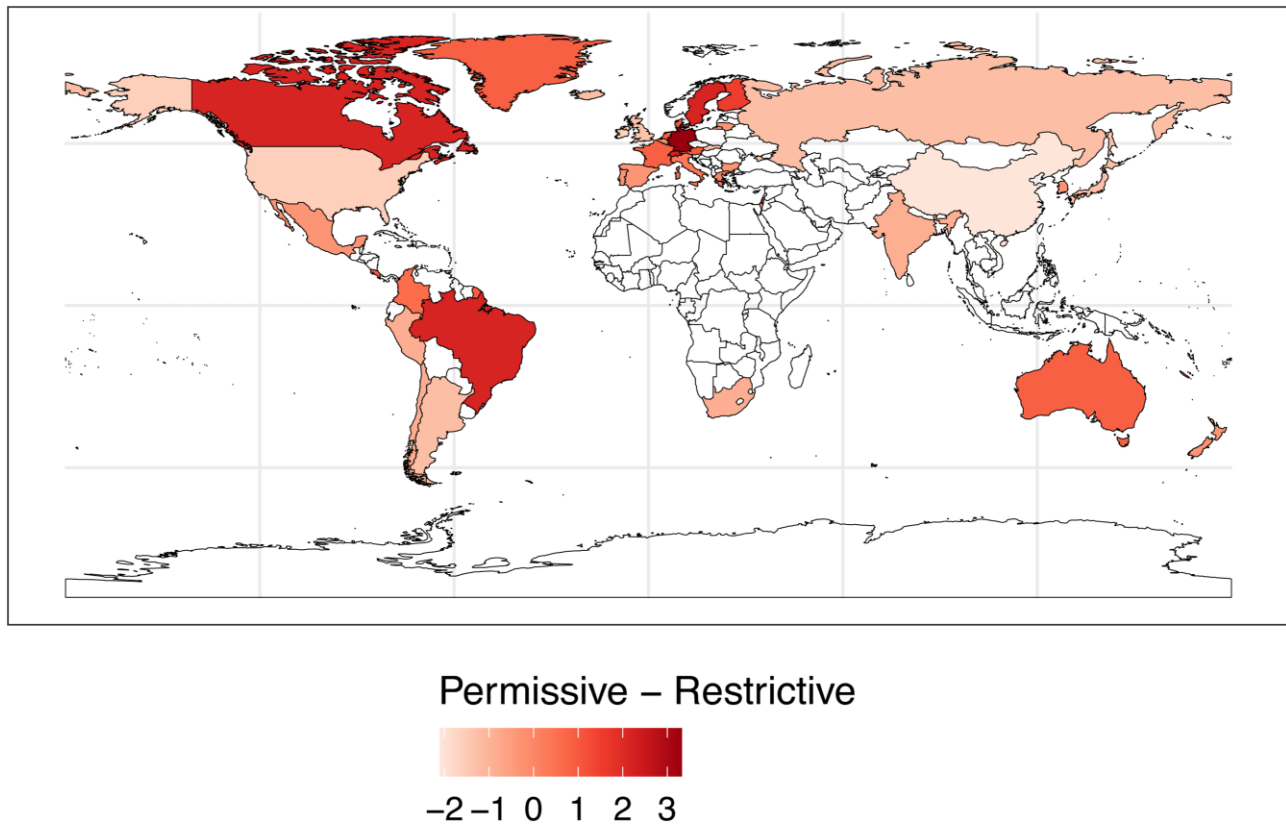


Figure 2. National regulation of gene-editing technology. Thirty-nine countries are rated by the permissiveness of national gene-editing technology regulations. Ratings combine data from [Isasi, Kleiderman, and Knoppers \(2016\)](#), [Araki and Ishii \(2014\)](#), and [Baylis et al. \(2020\)](#). See "Regulatory Arbitrage" section for details on the coding and source data.

and [Ogbogu 2019](#)). In many cases, however, outdated national regulations have simply not kept up with rapid advances in the field ([Baylis 2019](#)).

At the global level, there is growing interest in international coordination. Notably, the prospects for multilateral cooperation have not been plagued by the political cleavages common to other issue areas (e.g., geopolitical rivalries or North–South divisions). A set of legacy international agreements, negotiated in the 1990s in reaction to concerns about cloning, provide a precedent for global governance of genetic research.¹⁹ In recent years, however, formal international institutions have been slow to develop rules despite calls for new global standards.²⁰ The World Health Organization is among the few intergovernmental organizations explicitly addressing the issue, releasing a set of non-binding recommendations in 2021 for appropriate oversight of human genome editing ([WHO 2021](#)).

Arbitrage and Backlash in Gene-Editing Technology

CRISPR is clear case of a technological breakthrough that reduces the ability of states to independently regulate gene-

¹⁹The 1997 Oviedo Convention prohibits human cloning, genetic screening for non-health purposes, and the misuse of innovations in biomedicine and bans. The 1997 Universal Declaration on the Human Genome and Human Rights and subsequent UNESCO declarations address genetic data and trade in genetic resources.

²⁰In 2016, environmental activists unsuccessfully pushed for the UN Convention on Biological Diversity to expand its mandate to regulate synthetic biology and gene drive organisms.

editing research and applications due to its low cost and high public salience. While there are longstanding concerns about regulatory arbitrage in genetic research,²¹ the CRISPR breakthrough has increased both the demand and ability to circumvent regulatory constraints.

Gene-editing technologies are inputs to an array of commercial applications that are expected to grow substantially over the next decade. In 2019, the gene-editing market was worth approximately \$3.8 billion and is projected to exceed \$10 billion in the next 5 years ([Ugalmugle and Swain 2020](#)). The most direct applications are in the healthcare industry, where firms are developing gene therapies to address a range of disorders and chronic illnesses. Other sectors like agriculture, veterinary medicine, and industrial production processes also increasingly draw on gene-editing technology ([Brinegar et al. 2017](#)). Given the array of market applications, the competition for these economic returns is fierce.

Firms have lobbied governments to lower regulations on the technology in order to capture these economic benefits. European plant breeders have pressed the EU to relax gene-editing restrictions, arguing that existing rules put them at a competitive disadvantage.²² South Korea recently instituted a review of rules on gene therapy research in order to maintain its competitiveness in medical technology

²¹The potential for regulatory arbitrage was raised in the 1970s as several clinical trials moved to Europe and South America to sidestep burdensome rules in the United States ([Baskin et al. 2016](#)).

²²Max Planck Institute, "Regulating genome edited organisms as GMOs has negative consequences for agriculture, society and economy." <https://www.mpg.de/13748566/position-paper-crispr.pdf>.

(Ji-young 2017). In the United States, the government bowed to agricultural producers' demands to weaken restrictions on gene-edited crops and livestock (Cancryn and Crampton 2021). Other countries have announced similar regulatory reviews or new public initiatives to capitalize on gene-editing technologies.²³

When regulatory barriers remain, actors have moved research and development to more permissive jurisdictions. Baylis (2019) describes several incidents in which US-based scientists relocated genetic research on embryonic DNA to clinics in Mexico and Ukraine "so as to not violate US federal law" (46).²⁴ Isaacson (2021) similarly reports that entrepreneurs seeking to develop gene-editing applications in reproductive care openly acknowledge efforts to sidestep strict regulations.²⁵

As with other technologies, however, rapid progress has been accompanied by public anxiety and fears of misuse. Actors in both academia and industry are keenly aware that continued research depends on managing public anxiety about gene editing. Participants at a 2015 conference on gene editing, for example, called for slowing down the more controversial germline gene-editing research "in order to create a safe political space" (Isaacson 2021, 288). Historically, controversies regarding one application of gene-editing technology have diminished investor interest more broadly (Gardner 2020), as reflected in the Jesse Gelsinger tragedy. Advocates for scientific and national regulation of gene editing frequently cite "increasing legitimacy and trust" as a primary goal (Kuzma et al. 2018, 23). Aiyegbusi et al. (2020), for example, identify public perceptions of gene therapies as "central to their uptake and use."

Concern about inappropriate genetic modification escalated in 2018, when the Chinese scientist He Jiankui announced the birth of the world's first gene-edited infants. He used CRISPR to genetically alter several embryos in order to render them immune to HIV (Cyranski 2019). The revelation sparked an international outcry, raising concerns about safety, consent of the participants, and the risks of modifying traits that will pass to subsequent generations.²⁶ Calls for a global moratorium on some avenues of gene-editing research swiftly followed the revelation of He's experiment (Lander et al. 2019). Recognizing the potential for public backlash, leading scientists were quick to condemn the research. A senior colleague accused He of "jeopardizing the entire field of genetic engineering" (Isaacson 2021, 306).²⁷ Chinese scientists working in the field of gene editing expressed concern "that the international condemnation that followed He's explosive announcement in 2018 might have a wider chilling effect on CRISPR work in China" (Cyranski 2020).

²³ Policymakers in New Zealand are reviewing the country's gene-editing regulations (Morton 2019), and the Russian government recently announced a collaboration with Rosneft to develop gene-editing technology (Morton 2020).

²⁴ The Ukraine clinic now boasts patients from Ukraine, the United States, Israel, and Spain in further evidence of forum shopping for gene-editing products (Baylis 2019, 47).

²⁵ An entrepreneur responded to questions about Food and Drug Administration (FDA) regulations of CRISPR for gene-editing babies by saying that "clinics did not have to be in the United States. There would likely be other countries where the procedure would be allowed, and people who could afford gene-edited babies would be willing to travel" (Isaacson 2021, 286).

²⁶ In Online Appendix Section A.4, we illustrate this public backlash using data from Twitter posts surrounding the He Jiankui controversy. In a sample of over 50,000 tweets, we demonstrate that posts about gene-editing increase in volume, negative sentiment, and moral outrage in multiple countries following the scandal.

²⁷ After initially heralding the achievement, China sentenced He and two colleagues to 3 years in prison for "illegal medical practice" (Cyranski 2020).

In summary, the recent history of gene-editing research provides suggestive evidence that technological breakthroughs are associated with both public anxiety and attempts to evade stringent regulations. In the following section, we look for systematic evidence of regulatory arbitrage and public backlash spillovers in this field.

Empirical Tests

We present two empirical tests of the processes outlined above. First, we leverage data on scientific employment to examine whether technological breakthroughs affect the relocation of researchers to more permissive jurisdictions. Because we expect the CRISPR revolution to accelerate arbitrage behavior, we use the year in which CRISPR was introduced as a cutpoint in the analysis. We test whether gene-editing researchers are systematically more likely to move to countries with weaker regulations after 2012. We also examine whether countries with permissive regulations benefit from increased scientific collaboration, patent applications, and clinical trial development in this period.

For the second test, we examine whether technological controversies generate public backlash in both the home jurisdiction and foreign countries. We identify the presence of public backlash using an original online survey experiment on American respondents. We randomly assign information about a hypothetical gene-editing controversy and examine its effect on public support for gene-editing research and policy. The experiment varies whether the controversy occurs domestically or in a foreign country, allowing us to test whether misuse of gene-editing technology affects public attitudes in both the home jurisdiction and abroad.

Regulatory Arbitrage

We argue that, in the wake of technological breakthroughs, actors increasingly seek to evade strict regulations by relocating to jurisdictions with weaker rules. To test this claim, we analyze employment patterns of over 100,000 gene researchers. We also look for evidence of forum shopping in the commercial development of gene-editing technology using data on clinical trials and patent applications.

Our independent variable for these tests is the rigor of national regulations governing gene-editing technology. We develop a composite national regulatory score drawn from three distinct sources: Isasi, Kleiderman, and Knoppers (2016) rate the stringency of national regulations related to gene editing, Araki and Ishii (2014) focus on heritable gene-editing regulations, and Baylis et al. (2020) collect data on rules for research using genetically modified embryos.²⁸

The three measures are positively correlated but prioritize different applications of gene-editing technology. We combine them into a broad measure of each country's regulatory environment via principal components analysis. This provides a continuous, cross-national measure of gene-editing regulation for 39 countries that engage in gene research and clinical development.²⁹ Cross-national variation in these regulations is visualized in figure 2. The most restrictive regulatory environments include Germany and Sweden; the most permissive are China and Ireland. The regulatory scores are centered at zero and range from -2.1 to 3.3, with higher values indicating more restrictive regulations.

²⁸ Online Appendix A.7 details the construction of the composite measure.

²⁹ The three data sources vary widely in geographic coverage. Thirty-nine countries are classified by at least two sources. For these countries, we impute the missing scores before estimating the principal components.

To look for evidence of accelerated arbitrage, we examine whether gene scientists are more likely to relocate to countries with more permissive regulatory standards following the introduction of CRISPR in 2012. Theoretically, institutions located in countries with more permissive regulatory standards will be more attractive destinations for researchers in the post-CRISPR era. To measure scientific relocation, we examine employment patterns of researchers who have published scientific papers in the field of gene editing. We extract all published articles on the topic of “genetic engineering” from 2002 to 2021 from *PubMed*, a large database of biomedical publications. We match these articles with a separate database, *Web of Science*, to identify the institutional affiliations of the authors in the *PubMed* sample.³⁰ This process enables us to identify an author’s country of employment at the time of an article’s publication. The search yields approximately 120,000 papers and over 100,000 unique gene-editing researchers.

Using this record of scholarly publications, we construct a dataset of researcher movement. We structure our data as a series of directed country dyads. An observation reflects the number of gene researchers who relocate from country i to country j in year t .³¹ In the year 2005, for example, twelve scientists who were most recently employed in Japan published papers while employed in the United Kingdom. Another ten moved in the opposite direction, relocating from the United Kingdom to Japan. We also include observations representing scientists who remain in their “home country”: in 2005, 737 researchers most recently employed in the United Kingdom remained there and published papers. These counts of gene scientist relocations serve as the dependent variable in the tests below.

Of the 262,377 employment records we observe in our sample, 27% represent relocation across international borders while 73% remain in their country of prior employment. While international relocations occur for many reasons (institutional prestige, more generous funding, familial ties, etc.), we argue that the regulatory environment of each country shapes decisions on the margin and that the effect of regulatory differences will be larger in the CRISPR era.

To test these patterns systematically, we construct a variable, *Regulatory Difference*, that subtracts the former country regulatory score from the researcher’s country of current employment. Positive values mean that the destination country has stricter regulations than the origin country. We interact this variable with an indicator for the time period (2012–present) when the CRISPR breakthrough is hypothesized to accelerate forum-shopping behavior. These models exploit the technological shock of CRISPR to estimate how employment patterns respond to regulation in the wake of technological breakthroughs. We expect the introduction of CRISPR to magnify the effect of regulatory differences. If we are correct, we should observe a negative and statistically significant coefficient for the interaction term; this indicates that researchers are more likely to seek out permissive jurisdictions after the CRISPR breakthrough.

We include a battery of control variables to address confounders related to each country’s national economic out-

put, human capital, and commitment to research funding. We include GDP to account for each country’s overall economic capacity and GDP per capita for its level of development. To address the possibility that a country’s underlying scientific capacity drives both gene-editing regulations and employment patterns, we use several controls for scientific capital. These include an annual count of patent applications in a country (*Patents*) and a measure of annual R&D expenditure for each country.³² As an additional measure of scientific capacity, we include a count of the number of elite universities in each country (*Universities*), along with the average ranking of national universities according to the Times Higher Education World University Rankings.³³ Separately, we add an indicator for same-country pairings to account for the high propensity of researchers to remain employed in the same country over time. We include dyad fixed effects in some specifications to control for features specific to each country pair.

Table 1 reports the results of several linear models estimating the effect of regulatory difference on scientific relocation, before and after the CRISPR breakthrough. Standard errors are clustered by country dyad. Column 1 presents a baseline model with the *Regulatory Difference* measure, an indicator for 2012–present (*CRISPR*), and the interaction term. The positive and statistically significant coefficient for the *CRISPR* variable indicates a higher propensity for employment relocation after 2012. This suggests that the technological shock generally increased cross-border mobility of researchers. More importantly, the interaction term *Regulatory Difference* \times *CRISPR* is negative and significant, indicating that restrictive jurisdictions become substantially *less* attractive destinations after 2012. This result is consistent with enhanced flows of researchers into more permissive jurisdictions in the wake of the CRISPR breakthrough. Columns 2 and 3 find broadly similar results after adding the full set of covariates as well as dyad fixed effects. Substantively, a one-unit increase in *Regulatory Difference* reduces scientific relocation by approximately 0.03 researchers per year after the CRISPR breakthrough. This modest effect is meaningful once aggregated over the time period. For example, the results suggest that a high-regulation country like Germany has lost approximately 31 gene-editing researchers due to forum shopping from 2012 to 2019.

A possible challenge to inference is that permissive jurisdictions (e.g., China, Ireland, and the United States) may be attractive destinations for scientists for reasons other than their regulatory environment. While many potential motivations are addressed via control variables, we also conduct a placebo test to examine whether researchers in unrelated fields relocate to locations with permissive gene-editing regulations in this time period. In Online Appendix Table A1, we replicate the analysis above using employment patterns of researchers in an unrelated field. We see no equivalent shift in employment to low-regulation environments after 2012.

Finally, to gauge whether forum-shopping behavior extends beyond the relocation of gene scientists, we probe a series of other outcomes—scientific coauthorships, gene therapy clinical trials, and gene-editing patent applications—that might be similarly responsive to arbitrage behavior. These tests are structured at the country-year level and include the same control variables listed above. In Column 1

³⁰We exclude two sets of researchers: (1) those without a listed institutional affiliation and (2) those with very common names (appear 100 times or more in our sample). We classify each researcher’s country of employment using their institutional affiliation.

³¹As the ability of scientists in a given country to publish research may be related to the state of gene-editing technology, we restrict the sample to researchers who published at least one paper before the introduction of CRISPR in 2012. The data therefore reflect employment relocations among gene scientists who were active researchers before the technological shock.

³²GDP, patent, and R&D data are from the World Bank’s World Development Indicators.

³³The Times rankings include the top 1,906 global universities across 108 countries.

Table 1. Employment relocation of gene researchers. Linear model estimates for the volume of gene-editing researchers who relocate to institutions in another country. Columns 2 and 3 control for GDP, GDP per capita, Patent applications, R&D expenditures, and number and mean rank of elite higher education institutions (coefficients not shown; we include these measures for both the origin and the destination country). Standard errors are clustered by country dyad. Statistical significance is denoted by: * $p < 0.1$; ** $p < 0.05$; and *** $p < 0.01$.

	DV: Scientific relocation		
	(1)	(2)	(3)
Regulatory difference	-0.010 (0.010)	-0.025 (0.027)	-0.025 (0.027)
CRISPR	9.355*** (3.409)	7.703 (5.623)	1.971** (2.597)
Regulatory difference \times CRISPR	-0.025* (0.014)	-0.035** (0.017)	-0.035** (0.018)
Controls		✓	✓
Dyad Fixed Effects			✓
Observations	22,730	22,730	22,730

Table 2. Effect of national regulations on coauthorship, clinical trials, and patents. The table displays coefficient estimates and dyad-clustered standard errors from a linear model. Statistical significance is denoted by * $p < 0.1$; ** $p < 0.05$; and *** $p < 0.01$.

	Dependent variable:		
	Int'l coauthors (1)	Clinical trials (2)	Patents (3)
Regulation	412.26*** (90.319)	-259.682*** (26.415)	-37781.360*** (5630.606)
CRISPR	7.782*** (1.395)	2.164*** (0.622)	134.264** (53.068)
Regulation \times CRISPR	0.856 (0.728)	-1.083* (0.575)	-180.149*** (53.900)
Controls	✓	✓	✓
Observations	602	602	550

of table 2, we examine whether gene-editing researchers in highly regulated jurisdictions are incentivized to seek more international coauthors as an alternative means to evade national rules. The positive interaction coefficient suggests that scientists working in strict jurisdictions may have increased international coauthorship after 2012, but the estimated effect is not statistically significant. In Columns 2 and 3, we find evidence that strict regulatory environments tend to experience fewer registered clinical trials and a lower volume of relevant patent applications after the introduction of CRISPR in 2012.

Public Backlash

We next examine patterns of public backlash arising from gene-editing controversies. To do so, we implement a survey experiment that gauges the public's response to a hypothetical, norm-violating application of gene-editing technology. To measure whether backlash spans international borders, we examine both the effect of controversial activity in one's own country as well as activity in a foreign country.

The online survey was conducted in July 2020 on a sample of 1,075 Americans quota-sampled to US census margins.³⁴ We embed a vignette experiment designed to address two

questions: First, do controversies over the use of gene editing reduce public support for the technology and its potential applications? Second, does public backlash spill across national jurisdictions?

The structure of the experiment is visualized in figure 3. First, all respondents receive a basic summary of gene-editing technology. Subjects are then randomly assigned to either a control condition, in which they move directly to the outcome questionnaire, or a treatment condition which includes additional information about a gene-editing controversy. Among treated respondents, we randomize whether the controversy occurs in the United States, the United Kingdom, or China.

The initial description of gene-editing technology, presented to both control and treated respondents, reads as follows:

All organisms, from bacteria to lizards to humans, have molecules called DNA, or deoxyribonucleic acid. These DNA molecules contain the genetic code for each organism. DNA provides the instructions that determine an organism's physical characteristics and control how it develops, functions, and reproduces.

In recent years, scientists have developed new gene-editing technologies that can permanently alter an organism's DNA. These technologies allow scientists to make targeted changes to DNA molecules in plants and animals, modifying their biological traits. For ex-

³⁴See Online Appendix A.3 for full survey text and Table A2 for sample summary statistics. Our survey was conducted on the platform Lucid, and our pre-registration plan can be found under EGAP 20200505AA. We restrict our sample to individuals who passed pre-treatment attention checks.

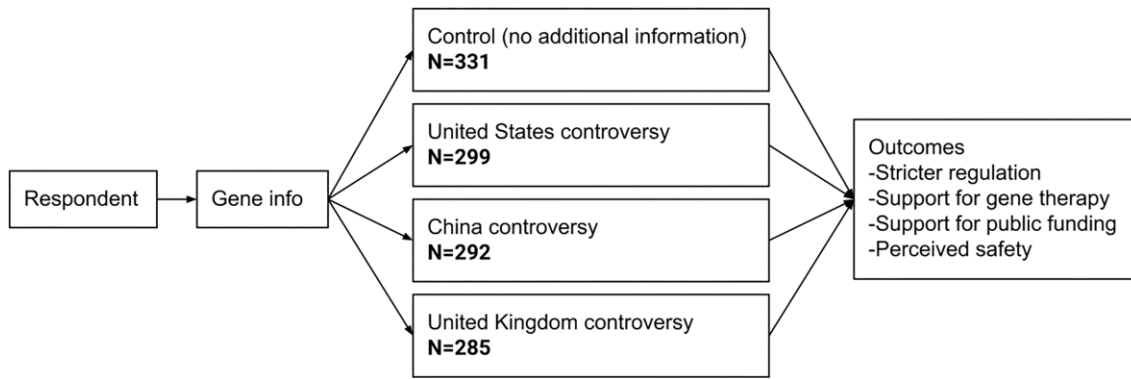


Figure 3. Survey schematic.

ample, scientists have edited the genes of wheat plants to make them easier to grow.

Respondents in the treatment condition are further shown a hypothetical news article set in the near future. To increase external validity, we model the experimental intervention on the real-world controversy surrounding He Jiankui. We present the text for the UK treatment condition here:

Birth of Genetically Altered Babies in the UK Provokes Outcry

January 25, 2021

[LONDON]—A British research team announced that they have used a new gene-editing technology to alter the DNA of a group of infants. In an unprecedented intervention, scientists on the research team deleted a set of genes believed to be linked to breast and prostate cancer. The deleted genes are not considered essential to basic biological functions in humans, but the long-term effects of their removal are unclear. The research team plans to periodically examine the infants throughout their lives to assess any side effects of the genetic alteration.

The disclosure this week of the research—carried out in the UK—has sparked urgent debate about the ethics of genetic alteration. The infants' birth represents a significant and controversial leap in the use of gene-editing technology. The British study has also increased concerns about a future in which parents produce “designer babies” with selectively improved traits, such as height or intelligence.

After treatment assignment, respondents rate their agreement with the following four statements on a scale of 0 (no agreement) to 10 (complete agreement).

- Research in the United States involving gene editing should be more strictly regulated.
- US patients should have access to medical treatments that involve gene editing.
- The US government should provide funding for gene editing research.
- Most US scientists conduct their research in a safe and responsible manner.

The statements estimate public confidence in the safety of gene-editing technology and support for continued development. Respondents' answers constitute our dependent variables in the analyses below.

Our argument about public backlash against breakthrough technologies generates two primary predictions. First, we expect respondents who read about a controversy in their own country will be less supportive of gene-editing research. If such “domestic public backlash” exists, the domestic controversy treatment should increase demand for strict regulation, decrease support for gene therapies, reduce willingness to fund gene-editing research and depress confidence in the safety of scientific research. Second, we expect foreign controversies to similarly reduce public support for gene editing among US respondents. An “international public backlash” occurs if the controversial use of gene editing generates a domestic backlash even when the scandal occurs in another country.

We report treatment effects for each outcome of interest in figure 4. Coefficients represent the treatment effect of exposure to a gene-editing controversy, compared to the control (no controversy) condition.³⁵ Within each panel, we display the effect of a domestic controversy, a foreign controversy in the United Kingdom, and a foreign controversy in China.

We find evidence of domestic public backlash in three of four outcomes. Relative to a baseline of reading only the introductory text, respondents who read about a hypothetical misuse of gene-editing technology by American researchers exhibit significantly less support for patient access to gene therapies ($p = 0.02$) and public funding for gene-editing research ($p < 0.01$). They also have diminished perceptions of the safety and responsibility of scientific research ($p = 0.05$) in the United States. On average, the domestic controversy treatment shifts opinion on each of these outcomes by approximately 0.5 points. Contrary to expectations, respondents do not increase demand for strict regulations in reaction to domestic gene-editing scandals ($p = 0.61$). This null finding may reflect a ceiling effect, as even respondents in the control condition call for strict regulations in high numbers (see Online Appendix Figure A4).

There is clear evidence that backlash is not limited by national jurisdiction. As in the domestic scenario, neither of the foreign scandals significantly affects attitudes about gene-editing regulation. However, support for public funding of gene-editing research significantly decreases in response to foreign controversies in the United Kingdom and

³⁵See Online Appendix Table A3 for point estimates and standard errors. Online Appendix Table A4 reports similar results among respondents who passed an alternative attention check.

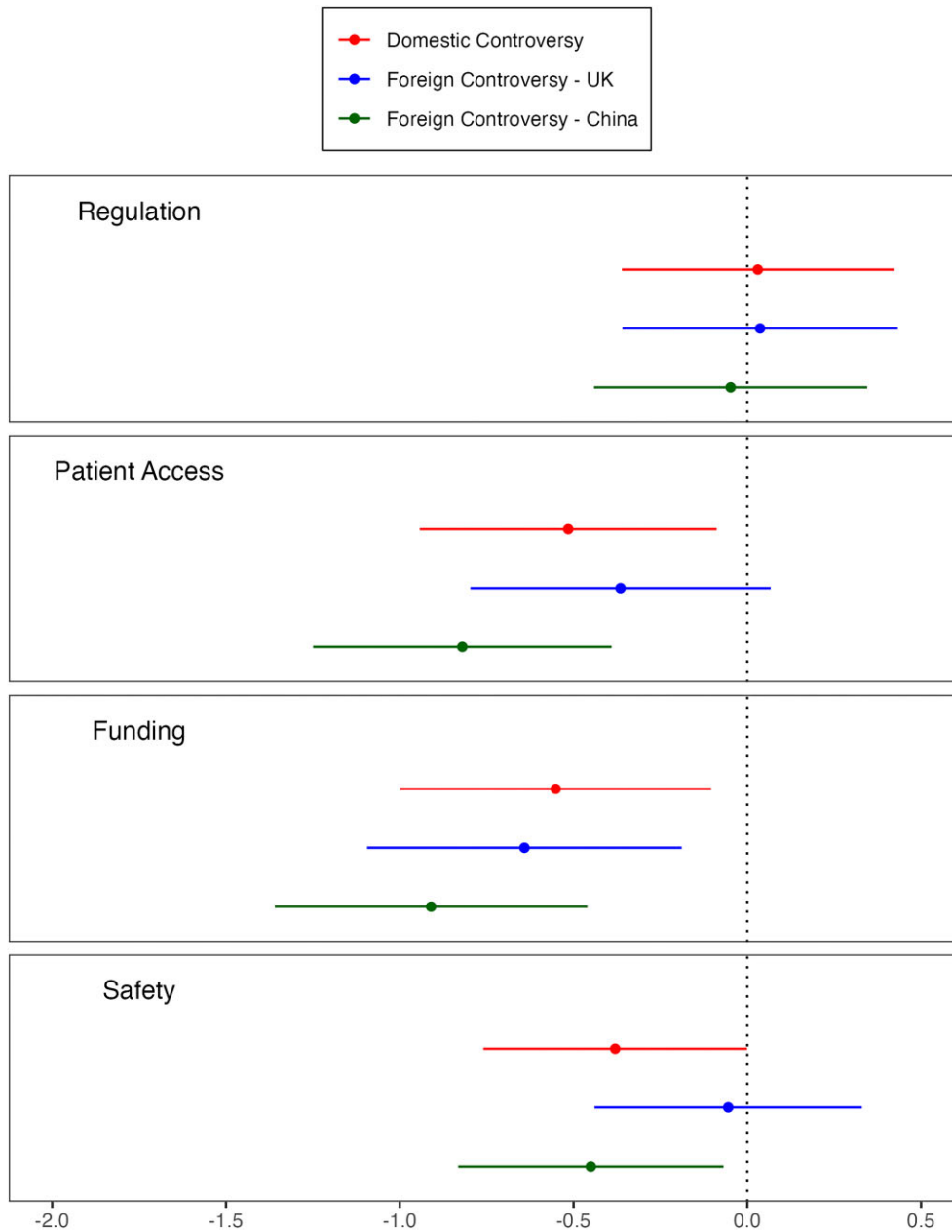


Figure 4. Public response to gene-editing controversy. The figure shows the treatment effect of a hypothetical gene-editing controversy in the United States, the United Kingdom, and China, with 95% confidence intervals. The panels report effects on the four dimensions of public support listed above.

China ($p < 0.01$). Respondents also reduce confidence in the responsibility of US scientists ($p = 0.02$) and support for gene therapies ($p < 0.01$) in the China condition. The UK controversy does not affect perceptions of safety but does decrease support for gene therapies ($p = 0.07$). Notably, the effects of domestic and foreign controversies are statistically indistinguishable across all four outcomes.

Together, these results suggest that the public does not discriminate between domestic and foreign research controversies. Controversial research in one national jurisdiction negatively impacts domestic support for gene editing in other countries for a number of public policy outcomes. Notably, we find this effect even though the foreign controversy imposes no direct material consequence on respondents. In-

stead, citizens appear to draw generalized inferences about the safety and morality of new technologies based on their use abroad.

Conclusion

This paper offers new insight into a set of regulatory challenges associated with governance of technological breakthroughs. Two processes complicate the task of governing these technologies: accelerated arbitrage behavior and the potential for international public backlash when controversies arise. Regulatory arbitrage is likely to occur when countries maintain disparate rules and breakthroughs increase the motivation to move to less strictly regulated jurisdictions. Using novel data on scientific employment, co-authorship,

clinical trials, and patents, we demonstrate that weaker national regulations lure more scientific talent and capital after the introduction of CRISPR technology.

Additionally, we show that controversial applications of technology trigger public backlash that readily spills across national boundaries. To our knowledge, we are the first to identify this process that links public attitudes about technology in one country to policy decisions in another. The effect of these controversies can be dramatic: in the history of gene editing, high-profile scandals led to collapsed public support, abandoned commercial applications, and harsh regulatory responses. We demonstrate the mechanism in an original survey experiment on American respondents and confirm its external validity using social media data from a real-life controversy. The implication of this finding is that the consequences of permissive regulation are not limited to a single country: if controversial misuse occurs in one jurisdiction, the resulting backlash spills across national boundaries.

Taken together, our results suggest that technological breakthroughs can create unique challenges for states as they craft national regulations. Breakthroughs accelerate regulatory arbitrage and threaten to destabilize public opinion through accidents or misuse in other countries—both of which erode the policy autonomy of states. These processes may provide states with compelling incentives to lower regulatory barriers: Each country can obtain individual economic benefits from weakening rules, while the risks of doing so are diffusely spread across multiple jurisdictions. If governments respond rationally to these incentives, effective regulation will be under-produced and the systemic risk of misuse may rise.³⁶ If misuse does occur, the resulting public backlash could reduce demand for the technology or lead to knee-jerk regulatory reactions, halting continued progress. While we do not test all of these implications in this paper, they provide promising avenues for future research.

Our empirical tests shed new light on the politics of biotechnology, an understudied but increasingly important domain. The processes we identify are also likely to recur in the governance of breakthrough technologies more generally. Future research expanding empirical tests to other fields is needed to assess the generalizability of our argument. In addition to contemporary technologies like artificial intelligence, historical disruptions such as the nuclear energy and information technology revolutions may have similarly presented regulatory challenges via these mechanisms. Different states may also be more or less susceptible to the mechanisms we posit: variation in domestic industries, historical experiences, regime type, and status concerns could affect countries' ability to manage governance in the face of technological breakthroughs.

By illuminating how regulation of breakthrough technology is constrained by interdependence across states, our findings make an implicit case for international policy coordination (Oye et al. 2014). International institutions are designed to manage interdependence and reduce transaction costs (Keohane 1984; Haggard and Simmons 1987). The recent guidelines adopted by the World Health Organization (WHO 2021) are consistent with this function. The recommendations establish a floor of basic ethical and safety protections and encourage harmonization of disparate rules governing the technology. If successful, this would limit the

scope for regulatory competition and reduce the risk of scandalous applications.

More broadly, our paper helps outline a new agenda for understanding how technological shifts affect regulation, interstate cooperation, and the demand for global governance. Emerging technologies shape a range of transnational spillovers in addition to the two we emphasize here. Genetic manipulation of the natural environment, including vegetation or insect populations, can easily traverse national jurisdictions. Similarly, the use of digital currencies may disrupt international financial systems or exacerbate collective action problems like carbon emissions. Advancements in artificial intelligence and robotics could reshape labor demand in ways that interact with the politics of trade, human rights, or military competition. Future work should test and expand upon these effects of technological innovation.

Supplementary Information

Supplementary information is available in the *International Studies Quarterly* data archive.

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³⁶While we do not directly test the effect of regulation on scientific scandals, we observe a positive correlation between weak regulatory environments and retractions in gene editing studies (see Online Appendix A.5).

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