

Does Technology Undermine Authoritarian
Governments?

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Abstract

Do advances in information and communications technology help topple authoritarian governments, or do they help such governments tighten their grip on power? Media figures, public intellectuals, and scholars have debated this relationship for decades. What is the net effect of technological advances on authoritarian control? We answer this question by analyzing the first game-theoretic model that accounts for the dual effects of technology. We show that, at lower levels of technology, innovation decreases an authoritarian government's grip on power, while, at higher levels of technology, further innovation strengthens the ability of authoritarian governments to stay in power. This indicates that the relationship between technology and the ability of authoritarian governments to stay in power is significantly more complex than the existing debate suggests. We conclude by discussing the implications of this result for scholars and policymakers interested in the effects of technology, authoritarianism, and the relationship between repression and dissent.

“Mass communication, in a word, is neither good nor bad; it is simply a force and, like any other force, it can be used either well or ill. Used in one way, the press, the radio and the cinema are indispensable to the survival of democracy. Used in another way, they are among the most powerful weapons in the dictator’s armory.”

Aldous Huxley (1958)

Do advances in information and communications technology (ICT) help topple authoritarian governments, or do they help such governments tighten their grips on power? Just as many have argued that centuries ago the printing press weakened the Catholic Church and contributed to the downfall of absolute monarchism in Europe (Habermas 1991), in recent decades prominent thinkers have contemplated how modern technologies might change every aspect of human society (Gore 1991; Gates et al. 1995; Diamond 2010). As the pace of technological innovation continues its seemingly inexorable acceleration, understanding how it might affect the relationship between state and society is one of the most important questions for the years to come. A deeper understanding of the effects of technology on authoritarian governments can also, in turn, deepen our understanding of the conditions under which governments facilitate or allow the adoption of new technologies as well as the relationship between technology and other structural factors that affect authoritarian survival.

Because of the important consequences of this issue, the debate over the effects of technological change has commanded considerable attention from policymakers and scholars alike, but empirical work has not yielded consistent results (Reuter and Szakonyi 2015; Shapiro and Siegel 2015). Some argue that technological advancement aids civil society groups and

individuals in collectively mobilizing to bring down authoritarian rule (Diamond 2010). From the fax machines of the Tiananmen Square protests in 1989 to the more recent use of social media platforms during the Arab Spring, anti-government groups have famously used the latest technologies to mobilize their efforts. Yet the same technologies also allow governments to monitor their opponents and control the flow of information (Milner 2006; Morozov 2012; Dickson 2016), potentially allowing authoritarian governments to prevent and crush any organized opposition. Among the most notorious examples are widespread wiretapping and recording of phone conversations by the East German regime, blocking and filtering Internet content in China and Iran, and the more recent use of online monitoring technologies to eavesdrop and track the activities of anti-government activists in Russia and Egypt. Used in these ways, technology strengthens, rather than weakens, authoritarian governments.

Which of these perspectives is correct? Existing work has faced several important challenges that complicate analysts' ability to answer this question. First, technology affects both the ability of opposition groups to mobilize and the ability of governments to prevent such mobilization. Even if one could measure both effects, determining the net effect is a more complex task than measuring which individual effect is larger. Assessing the net effect of technology requires understanding its role in the complex strategic relationship between authoritarian governments and those who seek to topple them. Second, changes in technology are correlated in time and space with other social changes that can affect the ability of authoritarian governments to stay in power. New technologies tend to be more quickly adopted in growing economies; reduced barriers to trade can also facilitate technological change. Therefore, understanding the causal relationship between technology and the stability of authoritarian governments requires isolating the effect of technological innovation,

no simple task given that the empirical counterfactual is unobservable. A third challenge is that technological development may be endogenous to an authoritarian government’s ability to retain power; in many contexts, governments have the ability to promote or limit the adoption of technology in their societies. Addressing this requires a theoretically grounded understanding of the conditions under which such governments do or do not prefer technological innovation. While quasi-experiments may be helpful in addressing these challenges, they must be also guided by rigorous theory. Among other issues, the effects of technology may be more complex than analysts might initially conjecture (as this paper will demonstrate). As Farrell (2012: 38) cautions, “those who assume a simple relationship between new technologies and political outcomes may be making very serious mistakes.”

Motivated by these challenges, we provide a theory that accounts for the strategic complexity of how technological developments affect an authoritarian government’s grip on power. We model the interaction between an authoritarian government and an opposition group. The model accounts for the dual effects of technology by assuming that innovation lowers both the cost of preventive repression and the cost of organizing dissent.¹ Because technological change affects this strategic interaction, its net effect depends on (a) how the government reacts to anticipated changes in the opposition’s ability to organize dissent; and

¹The model contributes to a broader literature that uses formal models to analyze repression and authoritarian politics (Moore 2000; Siegel 2011*a,b*; Dragu and Polborn 2013; Svulik 2008, 2012, 2013; Rundlett and Svulik 2015; Gehlbach, Sonin and Svulik 2016; Paine 2016). While others have recently described the dual effects of technology (Dafoe and Lyall 2015; Rød and Weidmann 2015; Shapiro and Siegel 2015) and others have theoretically analyzed them individually (Little 2016), ours is the first strategic model of the dual effects of technology.

(b) how the opposition reacts to anticipated changes in the government's ability to prevent such mobilization. On the one hand, a higher level of technology increases the equilibrium level of preventive repression because the government anticipates that the opposition's ability to mobilize dissent has become less costly, so the government has a strategic incentive to increase its preventive repression. On the other hand, a higher level of technology can actually decrease the opposition's equilibrium effort to organize dissent because the opposition, anticipating increased preventive repression by the government, finds it more difficult to successfully organize dissent in the face of the government's increased effort to prevent such mobilization.

Because technological innovation can have this chilling effect on the opposition, we show that technological developments increase the probability of government downfall at relatively low levels of technology, while further technological innovations strengthen the ability of authoritarian governments to stay in power. Put another way, advances in technology increase the probability of government downfall, but only when such advances in technology occur at relatively low levels of technological development; at higher level of technological developments, further improvements in technology will reduce the probability of government downfall. By analyzing the dual effects of technology in a strategic context, we thus demonstrate that the relationship between technology and the probability of authoritarian downfall is not monotonic; it is neither direct nor inverse, as the two sides of the debate have previously argue. Ours is the first study we are aware of to posit a non-monotonic relationship between the level of technology and the probability of authoritarian downfall. This claim has important implications for the inferences we can draw from both existing and future empirical work: even if one can isolate technological change using a quasi-experimental design, one

might find either a positive or negative impact of technology on government downfall; our theory suggests that the external validity of such results may be limited to other societies on the same side of the non-monotonic relationship.

Another contribution of our model is that we derive predictions over the situations in which authoritarian governments prefer technological development. In reality, technological innovation is likely to be endogenous to the government's preference for strengthening its grip on power, so understanding when governments should have an interest in promoting such innovations can help address that endogeneity. Finally, by first isolating the effects of technology, our model in turn allows us to offer additional implications regarding the relationship between repression and dissent in authoritarian governments. While much work on the repression-dissent nexus has focused on how governments react to mobilized dissent (Hibbs 1973; Siegel 2011*a,b*; Hill and Jones 2014; Little 2016; Dragu and Lupu 2017), we contribute to our knowledge of these interactions by focusing on preventive repression, which has received less attention in recent work (Dobson 2012; Fariss and Schnakenberg 2013; Schnakenberg and Fariss 2014). Among other implications, our model suggests that, under a broad set of conditions, technological innovation would result in increases to preventive repression; its effects on mobilized dissent, on the other hand, are more conditional. We also examine how the effects of technology relate to other structural factors that can affect the probability of government downfall, which can include human rights institutions and norms. We offer implications about the ways in which the effects of technology on the probability of government downfall depend on the strength of such factors in a given society.

The remainder of this paper proceeds as follows. In the next section, we briefly discuss the key insights and findings upon which we build. We then describe and analyze our formal

model. In the following sections, we conduct a secondary analysis of alternative models of these interactions and compare the results of those models to our main specification. Finally, we discuss the implications of our analysis and conclude.

The Effects of Technology

Changes in technology have important effects on social conflict. As technology has rapidly advanced in recent decades, scholars have increasingly analyzed issues such as its role in political competition (Acemoglu and Robinson 2006), authoritarian politics (Reuter and Szakonyi 2015), and violence (Dafoe and Lyall 2015; Shapiro and Weidmann 2015; Shapiro and Siegel 2015; Rød and Weidmann 2015). Of particular interest is the relationship between technology and the stability of authoritarian regimes (Farrell 2012). Many argue that technology promotes the downfall of such governments by empowering civil society and lowering communication costs, thus facilitating the organization of protest movements and other forms of mobilized dissent (Shirky 2008; Howard 2010; Diamond 2010). Opposition groups in recent uprisings such as the Arab Spring have famously used social media to coordinate their activities (Tufekci 2017). As Dobson (2012: p. 3) notes, “Today, the world’s dictators can surrender any hope of keeping their worst deeds secret: if you order a violent crackdown—even on a Himalayan mountain pass—you know it will likely be captured on an iPhone and broadcast around the world.” We refer to this as the *mobilization effect* of technology. Empirical work has found, for example, that increases in Internet adoption rates are correlated with both transitions to democracy (Norris 2001) and greater levels of democracy (Milner 2006).

Without denying the beneficial effects of new communications technologies to opposition groups, many argue that technological advancements also empower authoritarian governments (Kalathil and Boas 2003; Morozov 2012). We define preventive repression as the set of activities governments use to prevent opposition groups from threatening their power, including opposition efforts to mobilize and organize public dissent. Preventive repression can include a wide range of tactics, including (but not limited to) censorship, surveillance, and confiscation of resources. Preventive repression is often the main line of defense for authoritarians, hence the Stroessner regime’s famous practice of “nipping in the bud” the possibility of any anti-government activist groups. The prevention of potential opposition from organizing and from being publicly heard has long been an essential feature of authoritarian governments, from the creation of Fouché’s secret police to augment Napoleon’s rule to Metternich’s use of political police to buttress the Habsburgs’ arbitrary power. “Rather than forcibly arrest members of a human rights group, today’s most effective despots deploy tax collectors or health inspectors to shut down dissident groups” (Dobson 2012: p. 5).

Technological innovation provides authoritarian governments a wider set of tools with which to conduct preventive repression. We refer to this effect of technology as the *preventive control effect*. Authoritarian leaders have consistently and effectively used technological tools for their own anti-democratic ends (Rodan 1998; Kalathil and Boas 2003; Aday et al. 2010; Lorentzen 2014; Dickson 2016). Recently, for example, such governments have used voice recognition to scan mobile networks, tracked citizens’ movement using GPS, read emails and text messages in order to monitor dissident groups and selectively censor information, and used malware and spyware to secretly turn on webcams built into personal laptops and microphones in cell phones. The Internet, in particular, facilitates the use of many tools

that benefit such governments, including firewalls, content filters, and sophisticated digital monitoring. As Tufekci (2017: p. xxviii) writes, “[s]urveillance and repression, do not operate primarily in the way that our pre-digital worries might have forecast. This is not necessarily Orwell’s *1984*. Rather than a complete totalitarianism based on fear and blocking of information the newer methods include demonizing online mediums, and mobilizing armies of supporters or paid employees who muddy the online waters with misinformation, information glut, doubt, confusion, harrasment, and distraction, making it hard for ordinary people to navigate the networked public sphere, and sort facts from fiction, truth from hoaxes. Many governments target dissidents by hacking and releasing their personal and private information to try to embarrass or harass them, rather than acting directly on their political communication.” The Chavez regime in Venezuela created a database that included detailed information on all Venezuelan registered voters. Although the database included a tremendous amount of information, the regime was able to distribute copies to officials around the country on a single disc. The regime also nationalized the country’s only Internet Service Provider. During the Arab Spring, China’s leaders used their ability to control the Internet to censor all mentions of the word “jasmine”, lest this signal be used to coordinate mobilized dissent against the government (Dobson 2012). In Ben Ali’s Tunisia, the government created an agency that provided Internet service but also facilitated preventive repression. All Internet traffic, including web access and e-mail, went through the agency, making it relatively easy for the government to monitor and censor traffic (Wagner 2012).

Technology thus impacts both the government’s ability to preventively stifle the mobilization of public protest and the opposition groups’ ability to mobilize dissent against the government. For example, while cellular phones can allow members of opposition groups to

communicate with each other, authoritarian governments can use this technology to monitor such communication and even locate these individuals before they can organize public actions. Likewise, while individuals may be able to access vast stores of information on the Internet and use social media to coordinate with each other, regimes such as China's have deployed an army of cyber-police, software developers, and web monitors to monitor, filter, and censor online information and communications. Any technology that has the potential to help dissenters organize may also have the effect of helping the authoritarian government stifle potential opponents before they can take actions that challenge the government. A recent United Nations report on the state of freedom of expression in the Internet age notes these dual effects of technological developments: "Innovations in technology have increased the possibilities for communication and protections of free expression and opinion, enabling anonymity, rapid information-sharing and cross-cultural dialogues. Technological changes have concurrently increased opportunities for State surveillance and interventions into individuals' private communications" (La Rue 2011).

The dual effects of technology are embedded in the strategic interaction between preventive repression and mobilization of dissent. "The same security features that appeal to users of the new platforms have brought them into conflict with governments," resulting in blocks, shutdowns, and legal actions against Internet apps and platforms (Freedom House 2016: p. 6). When considering whether to express disapproval of the regime, individuals fear retaliation from the government and find it difficult to exert effort to organize public dissent. Mobilizing public dissent is costly, and the success of activist movements and opposition groups often depends in part on finding ways to reduce these costs (Tilly 1978). In turn, public dissent threatens authoritarian leaders' ability to stay in power. In anticipation of

such challenges, leaders often choose to repress opposition groups before they have the capacity to organize large-scale protests to challenge the government's grip on power. Preventive repression can have multiple effects on dissenting groups. It can raise the cost of mobilizing to challenge the state by disrupting the dissenting group, cutting off their communication, making their assembly more difficult, and restricting access to resources (Tilly 1978: p. 100). Yet preventive repression is also costly to governments because it requires the expenditure of resources to collect information and act on it. In addition, leaders rely on agents to carry out their orders to repress, meaning that they must both compensate those agents and incur costs for possible agency loss (DeMeritt 2015; Svolik 2013).

What is the net effect of technological advances on an authoritarian government's grip on power? To answer to this question, we must analyze these effects within the context of the strategic interaction between preventive repression and opposition effort to organize dissent. The model we analyze below captures both effects of technology in the context of this strategic relationship.

The Model

The players are an autocratic government and an opposition group. The government chooses a level of preventive repressive effort $r \in [0, \bar{r}]$ in order to prevent the opposition from organizing dissent against the government's rule. The level of preventive repressive effort affects the probability that the government stops the opposition group from posing a challenge. The opposition group chooses a level of effort $p \in [0, \bar{p}]$ to organize and mobilize dissent activities to try to bring down the government. The opposition group's effort refers

to a wide range of activities, including (but not limited to) effort to organize riots, strikes, and protests. The level of opposition group effort affects the probability that the government will be able to remain in power.

Let $S(r)$ be the probability that the government prevents the opposition group from organizing, where a larger level of preventive repressive effort is more effective in doing so. The probability $S(r)$ is a twice continuously differentiable function that increases in r (i.e., $S' > 0$) and presents marginal decreasing returns in r (i.e., $S'' < 0$). No government has unlimited resources, so preventive repression is costly. The government's cost of preventive repressive effort is given by a function $C_g(r, t)$. Because of the preventive control effect of technology, the marginal cost of the government's preventive repressive effort decreases in the level of technology t . That is, the government's (marginal) cost of preventive repressive effort is lower when t is larger (i.e., technology is more advanced). The government's cost is a twice continuously differentiable function that increases in r (i.e. $\frac{\delta C_g(r, t)}{\delta r} > 0$) and is convex in r (i.e. $\frac{\delta^2 C_g(r, t)}{\delta r^2} > 0$).²

Conditional on the government not being able to prevent the opposition group from organizing (an event that occurs with probability $1 - S(r)$), a larger level of opposition effort increases the probability that dissent is successfully mobilized and thus the likelihood that the government falls. Thus, let $G(p)$ be the probability that the opposition group's

²We use the term "technology" to refer broadly to information and communication technologies, including methods, systems, and devices used for the storage, transmission, and retrieval of information. Examples include (but are not limited to) the printing press, radio, telephones, television, computers, and the Internet. Our definition encompasses both systems (e.g., satellite telephony) and individual applications (e.g., Twitter).

effort to mobilize public dissent is successful in bringing down the government (conditional on the government not being able to stifle the opposition group in the first place). This probability $G(p)$ is a twice continuously differentiable function that increases in the level of opposition effort (i.e. $G' > 0$) and presents marginal decreasing returns in p (i.e. $G'' < 0$). The opposition group's cost of organizing is given by a function $C_o(p, t)$ where the marginal cost of opposition effort is decreasing in the level of technology t . That is, the opposition group's marginal cost of dissent effort is smaller when t is larger (i.e., technology is more advanced), due to the mobilization effect of technology. The opposition group's cost is a twice continuously differentiable function that increases in p (i.e. $\frac{\delta C_o(p, t)}{\delta p} > 0$) and is convex in p (i.e. $\frac{\delta^2 C_o(p, t)}{\delta p^2} > 0$).

The outcome of the game is binary: the authoritarian government retains power or not. The government gets a payoff of 1 if it retains power and 0 if it is out of power. The opposition group has the opposite preference ranking over outcomes: it gets a payoff of 0 if the authoritarian government retains power and 1 if the government falls. The outcome of the game is a probabilistic function of the players' actions, as follows: with probability $[1 - S(r)]G(p)$, the outcome of the game is that the authoritarian government falls, and with the remaining probability the government retains power.

Given these specifications, the authoritarian government's payoff is

$$\begin{aligned}
 U_g &= S(r) \cdot 1 + [1 - S(r)][1 - G(p)] \cdot 1 + [1 - S(r)]G(p) \cdot 0 - C_g(r, t) \\
 &= 1 - G(p)[1 - S(r)] - C_g(r, t), \quad (1)
 \end{aligned}$$

and the opposition group's payoff is

$$\begin{aligned}
 U_o &= S(r) \cdot 0 + [1 - S(r)][1 - G(p)] \cdot 0 + [1 - S(r)]G(p) \cdot 1 - C_o(p, t) \\
 &= G(p)[1 - S(r)] - C_o(p, t). \quad (2)
 \end{aligned}$$

The opposition group and the government choose their actions simultaneously. Note that, as suggested in current public debates, advances in technology have a dual effect: they decrease the opposition group's (marginal) cost of mobilizing dissent intended to bring down the government, but they also decrease the government's (marginal) cost of preventing the opposition from posing a threat in the first place.

The Dual Effects Game

We solve for the Nash equilibrium of the game. The government's optimal action is the solution to the following maximization problem:

$$\max_r \{1 - G(p)[1 - S(r)] - C_g(r, t)\},$$

which implies that the government's optimal action is the solution to the following FOC equation:

$$S'(r)G(p) - \frac{\delta C_g(r, t)}{\delta r} = 0. \quad (3)$$

The government's optimal action $r(p, t)$ increases in p because, by the implicit function theorem:

$$\frac{dr}{dp} = -\frac{S'(r)G'(p)}{S''(r)G(p) - \frac{\delta^2 C_g(r,t)}{\delta r^2}} > 0,$$

which implies that the government exerts more preventive repressive effort to subdue the opposition group in the first place if the opposition group can be expected to exert more effort to organize dissent activities.

The opposition group's optimal action is the solution to the following maximization problem:

$$\max_p \{G(p)[1 - S(r)] - C_o(p, t)\},$$

which implies that the opposition's optimal action is the solution to the following FOC equation:

$$G'(p)[1 - S(r)] - \frac{\delta C_o(p, t)}{\delta p} = 0. \quad (4)$$

The opposition group's optimal action $p(r)$ decreases in r because

$$\frac{dp}{dr} = -\frac{-S'(r)G'(p)}{G''(p)[1 - S(r)] - \frac{\delta^2 C_o(p,t)}{\delta p^2}} < 0,$$

which implies that the opposition group exerts less effort to organize dissent against the government if the government can be expected to exert more preventive repressive effort.

The equilibrium actions are found by solving the system of equations given by expressions (3) and (4).³ Because the government's optimal action increases in p and the opposition's

³From a strategic perspective, the actions are strategic complements from the point of view of the government and strategic substitutes from that of the opposition group, which is similar to other asymmetric contests games such as terrorism prevention (Dragu 2017).

optimal action decreases in r , we have the following proposition:

Proposition 1. *The dual effects game has a unique pure strategy Nash Equilibrium.*

Given that the game has a unique pure strategy equilibrium, we can do comparative statics with respect to how technological developments (i.e., increases in t) affect the players' equilibrium actions.

Proposition 2. *In the dual effects game, the equilibrium level of preventive repressive effort increases when the level of technology increases (i.e., $r^*(t)$ increases in t). In the dual effects game, technological development leads to a decrease in the opposition group's equilibrium level of effort to mobilize dissent if*

$$-\frac{\delta^2 C_o(p, t)}{\delta p \delta t} < -\frac{\delta^2 C_g(r, t)}{\delta r \delta t} \cdot \frac{-S'(r)G'(p)}{S''(r)G(p) - \frac{\delta^2 C_g(r, t)}{\delta r^2}}, \quad (5)$$

and to an increase otherwise.

Proposition 2 indicates that a higher level of technological development leads unconditionally to an increase in the government's equilibrium level of preventive repressive effort. The intuition for this result is as follows. Because of the dual effects of technology, advances in technology work through two mechanisms—one direct and one strategic—on the government's equilibrium action. Directly, the decrease in the government's marginal cost of preventive repression (i.e., the preventive control effect) increases the government's ability to conduct more repressive effort. Strategically, while the mobilization effect of technology decreases the opposition group's marginal cost to organize dissent, the government anticipates this through its best response function (i.e., $r(p)$ increases in p), and thus the government

increases preventive repressive efforts in anticipation of the opposition groups's changed incentives. Thus, both the direct and strategic mechanisms on the government work in the same direction to increase the equilibrium level of preventive repression when t increases.

On the other hand, proposition 2 shows that technological development can either increase or decrease the opposition's equilibrium level of effort to mobilize dissent. Just as it does on the government, an increase in t works through direct and strategic mechanisms on the opposition's incentives to mobilize dissent, but these two mechanisms work in opposite directions. Directly, technological innovation decreases the opposition's cost of organized dissent, which, in turn, directly increases the opposition's equilibrium ability to organize dissent against the government. Strategically, on the other hand, technological innovation leads the opposition to expect an increase in preventive repression by the government because an increase in t decreases the government's cost of preventive repression. Because the optimal level of dissent effort decreases when the government's level of preventive repression increases, a larger t decreases the opposition group's equilibrium effort to mobilize dissent through this (strategic) chilling-effect mechanism.⁴

Because, under the conditions described above, the equilibrium level of preventive repression can increase while the equilibrium effort to organize dissent decreases, the equilibrium probability of government downfall can decrease when t increases. To further investigate the conditions under which the probability of government downfall decreases in t , let the probability of subduing the opposition group in the first place be given by $S(r) = r$ and the probability of successful effort to organize dissent activities be given by $G(p) = p$. Also,

⁴Expression (5) precisely states the general conditions under which the strategic chilling effect outweigh the direct effect.

let the cost of preventive repression and the cost of effort to mobilize dissent be given by $C_g(r, t) = \frac{1}{2}\frac{1}{t}r^2$ and $C_o(p, t) = \frac{1}{2}\frac{1}{t}p^2$, respectively. Given these specifications, the equilibrium probability of government downfall is

$$Pr(\text{government downfall}) = \frac{t}{(1+t^2)^2}.$$

Next, we analyze how technological innovations affect the equilibrium probability of a government downfall. We have the following result:

Proposition 3. *In the dual effects game, the equilibrium probability of government downfall increases in t for $t \leq \bar{t}$ and decreases in t for $t > \bar{t}$.*

Proposition 3 suggests that, at relatively low levels of technology, $t \leq \bar{t}$, advances in technology increase the equilibrium probability of authoritarian government downfall whereas when $t \geq \bar{t}$, further advances in technology decrease the equilibrium probability of government downfall. \bar{t} can be thought of as a technological turning point, beyond which the strategic chilling effect of increased preventive repression induces the opposition group's to lower its equilibrium level of effort to mobilize dissent. As such, advances in technology at such higher levels of t increase the equilibrium level of preventive repression effort and decrease the equilibrium level of opposition group's effort to mobilize dissent, both of which decrease the equilibrium probability of government downfall. Proposition 3 indicates that the relationship between advances in technology and the probability of government downfall is not monotonic, as it has often been assumed to be by both technology optimists and pessimists.

Our model also allows us to understand the government's incentives for allowing or pre-

venting certain technological developments. Technological innovation is likely to be endogenous to the government's preference for strengthening its grip on power. Therefore investigating how changes in the level of technology would affect the government's equilibrium payoff is a necessary first step to understanding what kinds of technological developments authoritarian governments would allow or would block. We have the following result:

Proposition 4. *In the dual effects game, the government's equilibrium payoff decreases in t for $t \leq \tilde{t}$ and increases in t for $t > \tilde{t}$.*

Proposition 4 indicates that the government's equilibrium payoff decreases in t when those advances are happening at lower levels of technological development. This is intuitive given that, at such levels of technology, advances increase the probability of government downfall. However, improvements in technology at an already high level of technological development provide greater benefits to authoritarian governments, as the equilibrium payoff increases in t . Thus, the qualitative effect of changes in t on the government's equilibrium payoff is similar to the effect of changes in t on the equilibrium probability of a government downfall.

What is the relationship between \bar{t} and \tilde{t} ? Are there conditions under which the government would prefer to allow technological development even if doing so increases the likelihood of a government downfall? Are there conditions under which the government would prefer not to allow technological development even if doing so decreases the likelihood of a government downfall? The threshold \tilde{t} , above which the government's equilibrium payoff increases in t , is greater than than the threshold \bar{t} , above which the equilibrium probability of government downfall decreases in t ⁵. This implies that the government would only prefer to

⁵We demonstrate this in the Appendix.

allow a level of technological development in the range of parameters in which an increase in the level of technological development decreases the equilibrium probability of government downfall (i.e., where $t > \tilde{t} > \bar{t}$). This observation also suggests that there are situations in which the government would not want to allow an increase in t even if it decreases the equilibrium probability of government downfall (i.e., where $\tilde{t} > t > \bar{t}$). To understand the rationale for this, it is important to recall that changes in t do not only affect the probability of government downfall, but also affect the cost of preventive repression because an increase in t increases the equilibrium level of preventive repression. The government only prefers increases in the level of technological developments such that $t > \tilde{t}$ (i.e., increases at levels at which the increase in the equilibrium cost of repression is relatively small compared to the reduction in the equilibrium probability of government downfall).

One-Sided Effects of Technological Development

To capture the dual effects of technology as suggested in existing public debates, our previous analysis pertains to a situation in which a change in t affects both the government's cost for preventive repression and the opposition groups's cost for mobilizing dissent. Yet our framework can be used to also analyze scenarios in which a change in t only affects one player's cost, i.e., technology has a mobilization effect only or a preventive control effect only. Such scenarios are realistically possible, for example, where there is a temporal lag between the mobilization effect of a technology and its preventive control effect, or vice versa. The emergence of a new technology might quickly reduce the cost of organizing dissent before a government has the opportunity to invest the resources needed to take advantage of its

preventive control effects. In theory, individual technologies might have strictly mobilization effects or strictly preventive control effects. A new application, such as “Whatsapp”, may reduce the cost of organizing dissent, but may not provide additional benefits to the government beyond the pre-existing Internet and telecommunications platforms on which this application runs (e.g., the ability to shut down or monitor traffic on any app). Likewise, governments can use automated facial recognition tools to monitor opposition groups, whereas such tools may not provide utility to opposition groups.

In this section, we provide a theoretical analysis of the scenarios in which (1) an increase in t only decreases the opposition group’s cost of organizing dissent (i.e., it has no preventive control effect); and (2) an increase in t only decreases the governments’ cost of preventive repression (i.e., it has no mobilization effects). This provides a comprehensive analysis of the ways in which changes in the level of technological development affect the players’ equilibrium incentives and the equilibrium outcome.

The Mobilization Effect Game

First, let us analyze the case in which a change in t only decreases the opposition’s marginal cost of organizing dissent. We label this model the “mobilization effect game”. Similar to the previous analysis, the game has a unique pure strategy Nash equilibrium, and we can analyze comparative statics on the effects of changes in t . In this situation, an increase in t always increases the opposition’s equilibrium level of effort because the marginal costs of such effort to mobilize dissent decrease. At the same time, an increase in t also always increases the government’s equilibrium level of preventive repression because

the government's optimal level of repression increases in the level of opposition effort. This leads to the following proposition:

Proposition 5. *In the mobilization effect game, both the equilibrium level of preventive repression and the opposition group's equilibrium level of effort to organize dissent increase with an increase in t .*

Because an increase in t increases both the equilibrium level of effort to organize dissent and the equilibrium level of preventive repression, this can decrease the equilibrium probability of government downfall. To delineate how changes in t affect this equilibrium probability, let us analyze the parametric model introduced in the previous section with the modification that the government's cost of preventive repression is independent of t , i.e., $C_g(r) = \frac{1}{2}r^2$. In this situation, the equilibrium probability of government downfall is $Pr(\text{government downfall}) = \frac{t}{(1+t)^2}$. This equilibrium probability increases in t for $t \leq \bar{t}$ and decreases in t for $t > \bar{t}$. This result is thus qualitatively similar to proposition 4. This means that technological development has a non-monotonic effect on the probability of government downfall even if the applicable technology only has a mobilization effect.

Next, let us analyze how an increase in t affects the government's equilibrium payoff. The government's equilibrium payoff is

$$U_g^*(t) = 1 - G(p^*(t))[1 - S(r^*(t))] - C_g(r^*(t)).$$

A change in t affects the government's equilibrium payoff through two mechanisms: it changes the opposition's equilibrium level of effort to organize dissent and changes the equilibrium level of preventive repression. By the envelope theorem, the effect of a change in t

that works through the government's equilibrium action has zero effect on the government's equilibrium payoff. As a result, the effect of a change in t on $U_g^*(t)$ is given by how such a change in t affects the opposition group's equilibrium action. Because the opposition's equilibrium level of effort increases in t and because the government's payoff decreases in p , an increase in t decreases the government's equilibrium payoff. This implies that governments would seek to prevent the adoption of technologies that only have a mobilization effect.

Putting together these results, we have the following proposition:

Proposition 6. *In the mobilization effect game, the equilibrium probability of government downfall increases in t for $t \leq \bar{t}$ and decreases in t for $t > \bar{t}$. In the mobilization effect game, the government's equilibrium payoff always decreases in the level of technology.*

A simple implication of proposition 7 is that an authoritarian government has a preference for censoring any technology that only has the effect of decreasing the cost mobilizing dissent.

The Preventive Control Effect Game

Second, let us analyze the game in which a change in t only affects the government's marginal cost of preventive repression, which we label the "preventive control effect game" (i.e., the opposition's cost is not affected by changes in t). Similar to the dual effects game, the government's optimal action increases in the level of opposition's effort to mobilize dissent, and the opposition's optimal action decreases in the level of preventive repression. Therefore, the game has a unique pure strategy Nash equilibrium.

In this game, an increase in t increases the equilibrium level of preventive repression because the government's marginal cost decreases. An increase in t decreases the opposition's

equilibrium action because the opposition's optimal level of effort decreases in the level of preventive repression. Thus, we have the following:

Proposition 7. *In the preventive control effect game, an increase in t increases the equilibrium level of preventive repression and decreases the opposition group's equilibrium level of effort to mobilize dissent.*

Because the equilibrium level of preventive repression increases in t while the equilibrium level of effort to mobilize dissent decreases in t , the equilibrium probability of government downfall decreases when the level of technology increases in t . Similar to the mobilization effect game, the effect of a change in t on $U_g^*(t)$ is given by how a change in t affects the government's equilibrium payoff through changes in the opposition's equilibrium action and through changes to the government's cost of preventive repression. Because the opposition group's equilibrium effort decreases in t , and the government's cost of preventive repression decreases in t , an increase in t increases the government's equilibrium payoff. This further implies, intuitively, that the government would want to promote technological developments that only decrease the cost of preventive repression.

Putting together these results, we have the following proposition:

Proposition 8. *In the preventive control effect game, the equilibrium probability of government downfall decreases when t is higher. In the preventive control effect game, the government's equilibrium payoff increases when the level of technological development is higher.*

A simple implication of proposition 8 is that the authoritarian government has a preference for allowing technological developments that only decrease the cost of preventive control.

Table 1 summarizes the results of our main model and the two alternative models with respect to the equilibrium effects of technology on the equilibrium probability of government downfall and the government’s equilibrium payoff.

Table 1: Equilibrium Effects of Advances in Technology

	P(Government Downfall)	Government’s Payoff
Dual Effects Game	↑ at low t & ↓ at high t	↓ at low t & ↑ at high t
Mobilization Effect Game	↑ at low t & ↓ at high t	↓ in t
Preventive Control Effect Game	↓ in t	↑ in t

Technology and Other Costs of Preventive Repression

The goal of our previous analysis was to isolate the effect of changes in the level of technology on preventive repression, mobilized dissent, and the equilibrium probability of government downfall, all else equal. However, factors other than the level of technology can affect the capacity of authoritarian governments to conduct preventive repression. These factors include (but are not limited to) institutions to protect the rights of the opposition and norms against the conduct of preventive repression. We therefore investigate the effect of technological advancements on a government’s grip on power when other factors affect the capacity for preventive repression.

To this end, let us return to our dual effects game and analyze how an increase in t affects the equilibrium probability of government downfall when the government's cost of preventive repression is $C_g(\alpha, r, t) = \frac{1}{2}\alpha\frac{1}{t}r^2$, where α captures variation in the government's repressive capacity due to factors other than technology. A larger α means that the government has a larger cost of preventive repression given the same level of t . All other parameters are as in the previous dual effects game. Given these specifications, the equilibrium probability of government downfall is

$$Pr(\text{government downfall}) = \frac{\alpha^2 t}{(\alpha + t^2)^2}.$$

Next, we analyze how technological innovations affect the equilibrium probability of a government downfall. We have the following result:

Proposition 9. *In the dual effects game, the equilibrium probability of government downfall increases in t for $t \leq \bar{t}(\alpha)$ and decreases in t for $t > \bar{t}(\alpha)$. The threshold $\bar{t}(\alpha)$ increases in α .*

Similarly to the previous analysis, proposition 9 indicates that an increase in t undermines the authoritarian government's grip on power at lower levels of technology, whereas an increase in t at higher levels decreases the equilibrium probability of government downfall. More importantly, the proposition suggests that the equilibrium threshold $\bar{t}(\alpha)$ increases in α . Generally speaking, this implies that the technological turning point given in proposition 3 may be different for different countries if countries vary with respect to their repressive capacity. More specifically, this implies that, when the cost of preventive repression due to factors other than technology is larger, the range of parameters for which technological developments undermine authoritarian governments is also larger. All else equal, therefore,

a given technological innovation is more likely to increase the probability of government downfall in polities in which the underlying cost of preventive repression is larger. This implies that technological developments might be more likely to lead to government downfall if such advancements are coupled with, for example, legal efforts to increase the cost of preventive repression or advocacy campaigns to strengthen human rights norms.

Implications and Conclusions

Scholars and policymakers have debated the relationship between technology and authoritarian control for decades. Conclusions differ, but many agree that technology can have conflicting effects: technology can allow information to be more easily shared, but also more easily censored and monitored. Thus, technology can both reduce the cost of organizing dissent, but also can facilitate the tracking and subjugation of opposition groups and activist movements in the first place. We construct a model that accounts for the dual effects of technology, allowing us to generate predictions regarding the net effect of technological change on an authoritarian government's grip on power. To do this requires us to consider the relationship between technology and authoritarian control in the context of contentious politics, i.e., the strategic interaction between preventive repression and the opposition's effort to organize dissent.

Our game-theoretic analysis suggests that advances in technology undermine an authoritarian government's grip on power, but only when such advances in technology occur at relatively low levels of technological development; at higher level of technological developments, further improvements in technology will strengthen the government's grip on power.

While existing analyses argue for a monotonic relationship between technological developments and the probability of authoritarian government downfall (although they disagree on its direction), we show that this relationship is more complex. This result has far-ranging implications for scholarship and policy. First, it suggests that both technology optimists and pessimists are correct, but only up to a point. Second, our results demonstrate the utility of game-theoretic analysis for answering questions of this type. Determining the net effect of technology cannot be achieved by simply discussing the two competing effects in isolation, but rather by understanding these competing effects within a strategic context. Our results indicate that, as technology continues to evolve and improve, both governments and private actors will need to more carefully analyze whether such advances serve their interests.

The underlying, non-monotonic relationship between technology and authoritarian downfall is likely to be difficult to observe directly. While we have modeled technology as exogenous, in reality technological change is often endogenous to the government's preferences and ability to control its entry into and diffusion in a polity. We have therefore analyzed the conditions under which governments are more or less likely to favor technological advances. Intuitively, if such advances only facilitate the mobilization of dissent, authoritarian governments would seek to prevent them, and vice versa. The dual effects game also shows that, at low levels of technology, the government would not support technological advances, but would do so at higher levels of technology. These predictions will be useful to future researchers analyzing when and why authoritarian governments allow, or attempt to block, the adoption of new technologies. Government efforts to promote or prevent the adoption of technology are often observable. By offering predictions about the relationship between these efforts and the underlying effects of technology, our model can allow researchers to

predict the effects of some technologies based on whether or not governments promote or block them. For example, when an authoritarian government does allow (or even promote) a new technology, our analysis suggests that technology is likely past the turning point and likely to reduce the probability of government downfall.

Finally, a consistent result across our main model and both secondary models is that advances in technology increase preventive repression by authoritarian governments. Much evidence suggests that preventive repression has indeed increased as technology has developed. A recent report by Freedom House indicates that, as a global average, individuals' Internet freedom declined in 2016 for the sixth consecutive year. In recent years, limits on individuals' use of the Internet and violations of individuals' speech rights on the Internet have both increased (Freedom House 2016). Following successful mobilization in countries like Egypt and Turkey, governments have adopted new technologies and increased their preventive repressive capacity to prevent a repeat of earlier uprisings (Tufekci 2017). While Fariss (2014) finds that respect for human rights has improved in recent years, his data focus on violent violations of physical integrity rights. By contrast, many preventive repressive tactics do not require physical violence. It may be the case that part of why governments resort less to physical integrity rights violations than they did in the past is that they are now better able to engage in non-violent forms of repression that prevent organized dissent in the first place. We hope to investigate this relationship further in future work.

Our result regarding the non-monotonic relationship between technology and government downfall raises important questions about the turning point in this relationship. Which real-world technologies are at the turning point (i.e., \bar{t}) at which the effects of technology change? We can offer some observations based on the analysis above. First, the turning

point is likely to differ based on the context. In any society, factors other than technology affect the marginal costs of preventive repression and mobilized dissent, and the relationship between those costs. This means that a particular technology may be below \bar{t} in a given time and space, but above it in another. In a society in which the cost of repression, independent of technology, is relatively small, \bar{t} will be at a lower threshold than in a society in which the cost of repression is relatively large. Thus, the greater the extent to which factors other than technology increase the cost of preventive repression, the more advanced the level of technology must be to reach the turning point.

The technological turning point is also likely related to two dictator's dilemmas commonly discussed by scholars of authoritarian politics. The first version of the dictator's dilemma refers to the fact that authoritarian governments may be able to foster popular support, and thus ensure their grip on power, by promoting economic development. On the other hand, promoting development also requires adopting new technologies that could empower opposition groups (Shultz 1984; Kalathil and Boas 2003). Implicit in this dilemma is the notion that technology can facilitate opposition. A key assumption in this dilemma is that new technologies associated with economic development have greater potential to hurt an authoritarian's grip on power than further it.

The second dictator's dilemma, identified by Wintrobe et al. (1998: 20), is that “[d]ictators cannot—either by using force or the threat of force, or by promises, even of vast sums of money or chunks of their empires—know whether the population genuinely worships them or worships them because they command such worship.” Such regimes repress dissent to remain in power, but overly repressing dissent may prevent them from being able to accurately gauge its strength. If an authoritarian government underestimates the extent of latent opposition

to its rule, it may suddenly find itself deposed.⁶ Technology plays a key role in this problem. The second dictator's dilemma is in part an information problem; the government seeks to allow just enough expression of dissent to gauge its strength, but not enough to allow dissent to mobilize. Different levels of technological development allow for different means of expressing dissent and collecting information about such dissent.

The threshold \bar{t} may be the level of technological development that allows an authoritarian ruler to begin to overcome both dilemmas. In order to overcome both dilemmas, the government requires a technology that meets three criteria: (1) generating economic development; (2) allowing opposition groups to express sufficient dissent for the government to determine the potential opposition's strength; and (3) allowing the government to sufficiently control such dissent and prevent opposition groups from organizing. Meeting both the second and third criteria may be the key, as many technologies do meet the first. The key to meeting criteria (2) and (3) may derive from the preventive control effect. As technology develops, its preventive control effects qualitatively change in important ways. At lower levels of technology, the preventive control effect can facilitate government information gathering, but doing so is relatively costly if information is not in digital form, contained in a centralized system, or easily searchable. It would be costly, for example, for the gov-

⁶This dilemma can be illustrated by the Augusto Pinochet regime's referendum in 1988 on whether its rule over Chile should be extended. Pinochet miscalculated: he was confident he would win the referendum and thus strengthen his rule (Butler and Ranney 1994: 7) (Muñoz 2008: 199), but ended up losing because he underestimated Chileans' disapproval of his regime and the opposition's ability to coordinate a campaign against him. After 15 years of repressive rule, he had few means of determining the extent to which Chileans truly supported him or had been expressing such support out of fear.

ernment to tap and listen to all of the population's land-line phone conversations. Yet at higher levels of technology the preventive control effect begins to facilitate relatively less costly search, filtering, and censorship functions that allow governments to gather massive amounts of information and control its diffusion. Although we reserve a thorough investigation of this point for future work, this suggests technologies above \bar{t} may be those that have large preventive control effects. Improvements in technology when the preventive control effects are large can drastically reduce the cost of preventive repression. When that is the case, opposition groups can anticipate concomitant increases in preventive repression and will be more likely to lay low.

Technologies with large preventive control effects may be those that are sufficiently centralized such that the government can control the flow of information without shutting it off. Land-line telephone technology is unlikely to meet these criteria because it would be prohibitively costly for the government to both allow individuals to use telephones and monitor their conversations to the extent necessary to censor and control them. Broadcast technology like radio and television can be more easily controlled by the government, but tightly censored or government-run stations may not allow for sufficient expression of dissent to meet criterion (2). Recent analyses suggest that allowing the expression of dissent while preventing organized dissent is precisely how the Chinese Communist Party uses the Internet to maintain power. The government has promoted a hugely successful economic development program by, among many other policies, allowing organizations and individuals to adopt Internet technologies. The government also allows individuals to express disapproval of at least some of its policies, which allows it to gauge levels of public support. Yet the government uses its central control of the Internet to selectively censor content that might facilitate

collective action (Dobson 2012).

Dissent and preventive repression are closely, strategically linked, and our analysis suggests that their relationship is conditioned by technology and its effects. For example, when technology lowers only the costs of mobilizing dissent, the mobilization effect game predicts advances in technology to lead to increases in both dissent and repression. However, when technology lowers only the costs of preventive repression, the preventive control effect game predicts advances in technology to lead to increases in preventive repression accompanied by decreases in efforts to mobilize dissent. Finally, the dual effects game suggests a non-monotonic relationship between technological advances and dissent, accompanied by increases in preventive repression. This set of theoretical results is interesting in part because it mirrors the uncertainty in empirical studies of the relationship between dissent and repression, with existing results ranging from a direct, inverse, convex, and concave relationship between these phenomena (Moore 1998). Our theory therefore suggests that including measures of technology in such analyses may improve future empirical studies of this relationship and potentially facilitate progress in this debate.

The framework we develop also has implications for the effects of human rights laws and norms. As noted above, in a given society \bar{t} depends on other factors that affect the cost(s) of mobilizing dissent and/or preventive repression. A potential implication of this is that, if and to the extent human rights norms and institutions are weaker in more autocratic states (as many analyses suggest), then the turning point in such states is at a less advanced level of technology than it is in democratic states. Thus, those who advocate for the adoption of new technology in the name of democratization should take caution: such technology may be least effective in promoting authoritarian government downfall in the contexts in which such

change is needed most. Technology alone may not be sufficient to promote authoritarian downfall. Instead, it is more likely to be effective in doing so when accompanied by other changes that increase the cost of preventive repression (and thus push the turning point to a more advanced technology).

Although we conceptualize t as the level of information and communications technology, analytically viewing it as an alternative concept can yield potentially useful insights. For example, as Bueno de Mesquita and Downs (2005) note, economic development can reduce the cost of organizing dissent activities. Yet, as they argue, this does not necessarily lead to an increase in the probability of authoritarian government downfall. Note that their informal argument is in some ways similar to the mobilization effect game, except that the factor reducing the cost of dissent in their argument is development. Our model's conclusions are similar to theirs in the sense that we show that when only the cost of organizing dissent is decreased, the effect on the probability of government downfall is ambiguous.

Legal constraints and punishments, including constitutional and international law, are among the factors often argued to affect the cost of preventive repression (Nalepa 2008; Simmons 2009; Lupu 2015). Because law is generally thought to increase the cost of preventive repression, by reversing the direction of the predictions generated by the preventive control effect game and re-conceiving of t as being the level of legal constraints, we can further extrapolate from our results. Doing so would suggest that, if and to the extent legal constraints make preventive repression more costly, they would decrease preventive repression but increase mobilized dissent, which, interestingly, accords with theoretical expectations and empirical tests about the effects of international human rights law Conrad and Ritter (2016). This further indicates the usefulness of future work analyzing the relationship

between technology, preventive repression, and dissent.

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Online Appendix

Proof of Proposition 1. The government's optimal action is the solution to the following FOC equation:

$$S'(r)G(p) - \frac{\delta C_g(r, t)}{\delta r} = 0.$$

The second order condition is $S''(r)G(p) - \frac{\delta^2 C_g(r, t)}{\delta r^2} < 0$, which implies that the government's payoff is concave in its own action. The opposition group's optimal action is the solution to the following FOC equation:

$$G'(p)[1 - S(r)] - \frac{\delta C_o(p, t)}{\delta p} = 0.$$

The second order condition is $S''(r)G(p) - \frac{\delta^2 C_g(r, t)}{\delta r^2} < 0$, which implies that the opposition group's payoff is concave in its own action. Because (a) each player's action set is compact; (b) each player's payoff is continuous in the other player's action; and (c) each player's payoff is concave in its own action; following Dasgupta and Maskin (1986), the game has a pure strategy Nash equilibrium. Furthermore, the equilibrium is unique because the government's reaction function $r(p)$ is strictly increasing in p , and the opposition group's reaction function $p(r)$ is strictly decreasing in r , which implies that the reaction functions can only intersect once. □

Proof of Proposition 2. Because the government's and the opposition group's best response functions are continuous in t , we can apply the implicit function theorem to see how the equilibrium actions vary with an increase in t . The dependence of $r^*(t)$ on t is found by totally differentiating (3) and (4) with respect to t , which yields the system of equations

$$S''(r)G(p)\frac{dr}{dt} + S'(r)G'(p)\frac{dp}{dt} - \frac{\delta^2 C_g(r,t)}{\delta r^2} \frac{dr}{dt} - \frac{\delta^2 C_g(r,t)}{\delta r \delta t} = 0$$

$$[1 - S(r)]G''(p)\frac{dp}{dt} - S'(r)G'(p)\frac{dr}{dt} - \frac{\delta^2 C_o(p,t)}{\delta p^2} \frac{dp}{dt} - \frac{\delta^2 C_o(p,t)}{\delta p \delta t} = 0.$$

Solving the system of equations, we get

$$\frac{dr}{dt} = \frac{([1 - S(r)]G''(p) - \frac{\delta^2 C_o(p,t)}{\delta p^2}) \frac{\delta^2 C_g(r,t)}{\delta r \delta t} - \frac{\delta^2 C_o(p,t)}{\delta p \delta t} S'(r)G'(p)}{([1 - S(r)]G''(p) - \frac{\delta^2 C_o(p,t)}{\delta p^2})(S''(r)G(p) - \frac{\delta^2 C_g(r,t)}{\delta r^2}) + [S'(r)G'(p)]^2}.$$

The denominator and the numerator are positive and, as a result, $r^*(t)$ increases in t , as claimed.

Because the government's and the opposition group's best response functions are continuous in t , we can apply the implicit function theorem to see how the equilibrium actions vary with an increase in t . The dependence of $p^*(t)$ on t is found by totally differentiating (3) and(4) with respect to t , which yields the system of equations

$$S''(r)G(p)\frac{dr}{dt} + S'(r)G'(p)\frac{dp}{dt} - \frac{\delta^2 C_g(r,t)}{\delta r^2} \frac{dr}{dt} - \frac{\delta^2 C_g(r,t)}{\delta r \delta t} = 0$$

$$[1 - S(r)]G''(p)\frac{dp}{dt} - S'(r)G'(p)\frac{dr}{dt} - \frac{\delta^2 C_o(p,t)}{\delta p^2} \frac{dp}{dt} - \frac{\delta^2 C_o(p,t)}{\delta p \delta t} = 0.$$

Solving the system of equations for $\frac{dp}{dt}$, we get

$$\frac{dp}{dt} = \frac{([1 - S(r)]G''(p) - \frac{\delta^2 C_o(p,t)}{\delta p^2}) \frac{\delta^2 C_o(p,t)}{\delta p \delta t} + \frac{\delta^2 C_g(r,t)}{\delta r \delta t} S'(r)G'(p)}{([1 - S(r)]G''(p) - \frac{\delta^2 C_o(p,t)}{\delta p^2})(S''(r)G(p) - \frac{\delta^2 C_g(r,t)}{\delta r^2}) + [S'(r)G'(p)]^2}.$$

The denominator is positive and the numerator is negative if

$$([1 - S(r)]G''(p) - \frac{\delta^2 C_o(p, t)}{\delta p^2}) \frac{\delta^2 C_o(p, t)}{\delta p \delta t} + \frac{\delta^2 C_g(r, t)}{\delta r \delta t} S'(r)G'(p) < 0,$$

which implies that the $p^*(t)$ decreases in t if

$$-\frac{\delta^2 C_o(p, t)}{\delta p \delta t} < -\frac{\delta^2 C_g(r, t)}{\delta r \delta t} \cdot \frac{-S'(r)G'(p)}{S''(r)G(p) - \frac{\delta^2 C_g(r, t)}{\delta r^2}},$$

and increases otherwise, as claimed. □

Proof of Proposition 3. The equilibrium probability of government downfall is given by the following expression:

$$Pr(\text{government downfall}) = [1 - S(r^*)]G(p^*) = \frac{t}{(1 + t^2)^2},$$

which implies that the effect of a change in t on the equilibrium probability of government downfall is given by the following expression:

$$\frac{\delta}{\delta t} \{[1 - S(r^*)]G(p^*)\} = \frac{(1 - 3t^2)}{(1 + t^2)^3}.$$

Because $t > 0$, the equilibrium probability of government downfall increases in t if $1 - 3t^2 > 0$ and decreases in t otherwise. This implies that the equilibrium probability of government downfall increases in t if and only if

$$t \leq \bar{t} = \sqrt{\frac{1}{3}},$$

and decreases in t if $t > \bar{t} = \sqrt{\frac{1}{3}}$, as claimed. □

Proof of Proposition 4. The government's equilibrium payoff is

$$U_g^*(t) = 1 - \frac{2t + t^3}{2(1 + t^2)^2},$$

which implies that the effect of a change in t on the government's equilibrium payoff is given by the following expression:

$$\frac{\delta}{\delta t} \left\{ 1 - \frac{2t + t^3}{2(1 + t^2)^2} \right\} = \frac{1 - 2 + 3t^2 + t^4}{2(1 + t^2)^3}.$$

Because $t > 0$, the government's equilibrium payoff increases in t if $-2 + 3t^2 + t^4 > 0$ and decreases in t otherwise. This implies that the government's equilibrium payoff increases in t if and only if

$$t > \tilde{t} = \sqrt{\frac{-3 + \sqrt{17}}{2}}, \tag{6}$$

and decreases in t if $t \leq \tilde{t}$, as claimed.

Notice the threshold \tilde{t} is larger than \hat{t} because

$$\tilde{t} = \sqrt{\frac{-3 + \sqrt{17}}{2}} > \hat{t} = \sqrt{\frac{1}{3}},$$

as claimed. □

Proof of Proposition 5. In the mobilization effect game, because the government's and the opposition group's best response functions are continuous in t , we can apply the implicit function theorem to see how the equilibrium actions vary with an increase in t . The depen-

dence of $p^*(t)$ on t is found by totally differentiating the government's and the opposition group's FOCs with respect to t , which yields the system of equations

$$S''(r)G(p)\frac{dr}{dt} + S'(r)G'(p)\frac{dp}{dt} - \frac{\delta^2 C_g(r)}{\delta r^2} \frac{dr}{dt} = 0$$

$$[1 - S(r)]G''(p)\frac{dp}{dt} - S'(r)G'(p)\frac{dr}{dt} - \frac{\delta^2 C_o(p,t)}{\delta p^2} \frac{dp}{dt} - \frac{\delta^2 C_o(p,t)}{\delta p \delta t} = 0.$$

Solving the system of equations for $\frac{dp}{dt}$, we get

$$\frac{dp}{dt} = \frac{([1 - S(r)]G''(p) - \frac{\delta^2 C_o(p,t)}{\delta p^2}) \frac{\delta^2 C_o(p,t)}{\delta p \delta t}}{([1 - S(r)]G''(p) - \frac{\delta^2 C_o(p,t)}{\delta p^2})(S''(r)G(p) - \frac{\delta^2 C_g(r)}{\delta r^2}) + [S'(r)G'(p)]^2}.$$

Because both the numerator and the denominator are positive, this implies that $p^*(t)$ increases in t in the mobilization effect game, as claimed.

Similarly, solving the system of equations $\frac{dr}{dt}$, we get

$$\frac{dr}{dt} = \frac{-\frac{\delta^2 C_o(p,t)}{\delta p \delta t} S'(r)G'(p)}{([1 - S(r)]G''(p) - \frac{\delta^2 C_o(p,t)}{\delta p^2})(S''(r)G(p) - \frac{\delta^2 C_g(r)}{\delta r^2}) + [S'(r)G'(p)]^2}.$$

The denominator and the numerator are positive and, as a result, $r^*(t)$ increases in t in the mobilization effect game, as claimed. \square

Proof of Proposition 6. In the mobilization effect game, the equilibrium probability of government downfall is

$$Pr(\text{government downfall}) = \frac{t}{(1+t)^2},$$

which implies that the effect of a change in t on the equilibrium probability of government

downfall is given by the following expression:

$$\frac{\delta}{\delta t} \{ [1 - S(r^*)]G(p^*) \} = \frac{1 - t^2}{(1 + t)^3}.$$

Because $t > 0$, the equilibrium probability of government downfall increases in t if $1 - t^2 > 0$ and decreases in t otherwise. This implies that the equilibrium probability of government downfall increases in t if and only if

$$t \leq \bar{t} = 1,$$

and decreases in t if $t > \bar{t}$, as claimed.

The government's equilibrium payoff is

$$U_g^*(t) = 1 - G(p^*(t))[1 - S(r^*(t))] - C_g(r^*(t)),$$

and the envelope theorem implies that $\frac{\delta U_g^*(t)}{\delta t} = -\frac{\delta G(p^*(t))}{\delta p} \frac{\delta p^*(t)}{\delta t}$. Because $G(\cdot)$ increases in p and the opposition group's equilibrium level of effort increases in t , this implies that $\frac{\delta U_g^*(t)}{\delta t} < 0$, as claimed. \square

Proof of Proposition 7. In the preventive control effect game, the dependence of $r^*(t)$ and $p^*(t)$ on t is found by totally differentiating the government's and the opposition group's FOC with respect to t , which yields the system of equations

$$S''(r)G(p)\frac{dr}{dt} + S'(r)G'(p)\frac{dp}{dt} - \frac{\delta^2 C_g(r, t)}{\delta r^2} \frac{dr}{dt} - \frac{\delta^2 C_g(r, t)}{\delta r \delta t} = 0$$

$$[1 - S(r)]G''(p)\frac{dp}{dt} - S'(r)G'(p)\frac{dr}{dt} - \frac{\delta^2 C_o(p)}{\delta p^2} \frac{dp}{dt} = 0.$$

Solving the system of equations for $\frac{dp}{dt}$, we get

$$\frac{dp}{dt} = \frac{\frac{\delta^2 C_g(r,t)}{\delta r \delta t} S'(r) G'(p)}{\left([1 - S(r)] G''(p) - \frac{\delta^2 C_o(p)}{\delta p^2}\right) \left(S''(r) G(p) - \frac{\delta^2 C_g(r,t)}{\delta r^2}\right) + [S'(r) G'(p)]^2}.$$

The denominator is positive and the numerator is negative, which implies that the $p^*(t)$ decreases in t as claimed.

Solving the system of equations for $\frac{dr}{dt}$, we get

$$\frac{dr}{dt} = \frac{\left([1 - S(r)] G''(p) - \frac{\delta^2 C_o(p)}{\delta p^2}\right) \frac{\delta^2 C_g(r,t)}{\delta r \delta t}}{\left([1 - S(r)] G''(p) - \frac{\delta^2 C_o(p)}{\delta p^2}\right) \left(S''(r) G(p) - \frac{\delta^2 C_g(r,t)}{\delta r^2}\right) + [S'(r) G'(p)]^2}.$$

The denominator and the numerator are positive and, as a result, $r^*(t)$ increases in t , as claimed. □

Proof of Proposition 8. In the preventive control effect game, the equilibrium probability of government downfall is

$$Pr(\text{government downfall}) = G(p^*(t))[1 - S(r^*(t))]$$

Because the equilibrium level of preventive repression increases in t and the opposition group's equilibrium level of effort decreases in p , this implies that the equilibrium probability of government downfall always decreases in t in the preventive control effect game, as claimed.

The government's equilibrium payoff is

$$U_g^*(t) = 1 - G(p^*(t))[1 - S(r^*(t))] - C_g(r^*(t), t),$$

and the envelope theorem implies that $\frac{\delta U_g^*(t)}{\delta t} = -\frac{\delta G(p^*(t))}{\delta p} \frac{\delta p^*(t)}{\delta t} - \frac{\delta C_g(r^*(t), t)}{\delta t}$. Because $G(\cdot)$ increases in p and the equilibrium level of dissent decreases in t , and because $C_g(r^*(t), t)$ decreases in t , this implies that $\frac{\delta U_g^*(t)}{\delta t} > 0$, as claimed. \square

Proof of Proposition 9. The equilibrium probability of government downfall is given by the following expression:

$$Pr(\text{government downfall}) = [1 - S(r^*)]G(p^*) = \frac{\alpha^2 t}{(\alpha + t^2)^2},$$

which implies that the effect of a change in t on the equilibrium probability of government downfall is given by the following expression:

$$\frac{\delta}{\delta t} \{[1 - S(r^*)]G(p^*)\} = \frac{\alpha^2(\alpha - 3t^2)}{(\alpha + t^2)^3}.$$

Since $\alpha > 0$ and $t > 0$, the equilibrium probability of government downfall increases in t if $\alpha - 3t^2 > 0$ and decreases in t otherwise. This implies that the equilibrium probability of government downfall increases in t if and only if

$$t \leq \bar{t}(\alpha) = \sqrt{\frac{\alpha}{3}},$$

and decreases in t if $t > \bar{t}(\alpha) = \sqrt{\frac{\alpha}{3}}$. A simple inspection of $\bar{t}(\alpha)$ indicates that this threshold increases in α as claimed. \square

Robustness Appendix

In our model, technology affects the incentives of the government and the opposition group through their marginal costs: an increase in technology lowers the marginal cost of preventive repression and the marginal cost of mobilizing dissent to overturn the government. In this section, we show that our main results are robust to an alternative modeling specification in which technology affects the marginal incentives of the players through the probability of subduing the opposition and the probability of successfully mobilized dissent.

Therefore, let $S(r, t) = rt$ be the probability that the government subdues the opposition group where the marginal effectiveness of the government's preventive repressive effort is affected by the level of technology t . That is, the government's repressive effort is more effective in finding and subduing the opposition when t is higher. Also, let $G(p, t) = pt$ be the probability that dissent is successfully mobilized in bringing down the government (conditional on the government not being able to neutralize the opposition in the first place). All other parameters are similar to the model in the main text.

Given this specification, the authoritarian government's payoff is

$$\begin{aligned} U_g &= S(r, t) \cdot 1 + [1 - S(r, t)][1 - G(p, t)] \cdot 1 + [1 - S(r, t)]G(p, t) \cdot 0 - C_g(r) \\ &= rt + (1 - rt)(1 - pt) - \frac{1}{2}r^2, \end{aligned}$$

and the opposition group's expected payoff is

$$\begin{aligned}
 U_o &= S(r, t) \cdot 0 + [1 - S(r, t)][1 - G(p, t)] \cdot 0 + [1 - S(r, t)]G(p, t) \cdot 1 - C_o(p) \\
 &= (1 - rt)pt - \frac{1}{2}p^2. \quad (7)
 \end{aligned}$$

We solve for the Nash equilibrium of the game. The government's optimal action is the solution to the following maximization problem:

$$\max_r \{rt + (1 - rt)(1 - pt) - \frac{1}{2}r^2\},$$

which implies that the government's optimal action is the solution to the following FOC equation:

$$t^2p - r = 0. \quad (8)$$

The opposition group's optimal action is the solution to the following maximization problem:

$$\max_p \{(1 - rt)pt - \frac{1}{2}p^2\},$$

which implies that the opposition's optimal action is the solution to the following FOC equation:

$$(1 - rt)t - p = 0. \quad (9)$$

The equilibrium actions are found by solving the system of equations given by expressions (8) and (9). We have the following proposition:

Proposition 10. *The game has a unique pure strategy Nash Equilibrium. The government's*

equilibrium action is $r^* = \frac{t^3}{1+t^4}$ and the opposition's equilibrium action is $p^* = \frac{t}{1+t^4}$.

Given the equilibrium action of the government and the opposition group, we can compute the equilibrium probability of a government downfall:

$$Pr(\text{government downfall}) = [1 - S(r^*, t)]G(p^*, t) = \frac{t^2}{(1 + t^4)^2}. \quad (10)$$

Next, we can analyze comparative statics on how improvements in technology affect the equilibrium probability of a government downfall. We have the following result:

Proposition 11. *The equilibrium probability of government downfall increases in t for $t \leq \bar{t}$ and decreases in t for $t > \bar{t}$.*

Proof. The equilibrium probability of government downfall is given by the following expression:

$$Pr(\text{government downfall}) = [1 - S(r^*, t)]G(p^*, t) = \frac{t^2}{(1 + t^4)^2},$$

which implies that the effect of a change in t on the equilibrium probability of government downfall is given by the following expression:

$$\frac{\delta}{\delta t} \{ [1 - S(r^*, t)]G(p^*, t) \} = \frac{t(1 - 3t^4)}{(1 + t^4)^3}.$$

Because $t > 0$, the equilibrium probability of government downfall increases in t if $1 - 3t^4 > 0$ and decreases in t otherwise. This implies that the equilibrium probability of government

downfall increases in t if and only if

$$t \leq \bar{t} = \sqrt[4]{\frac{1}{3}}, \quad (11)$$

and decreases in t if $t > \bar{t} = \sqrt[4]{\frac{1}{3}}$, as claimed. \square

Similar to our main analysis, this proposition suggests that improvements in technology have increase the probability of government downfall at lower level of technological development. However, improvements in technology from an already high level of technological development help authoritarian governments to increase their grip on power.